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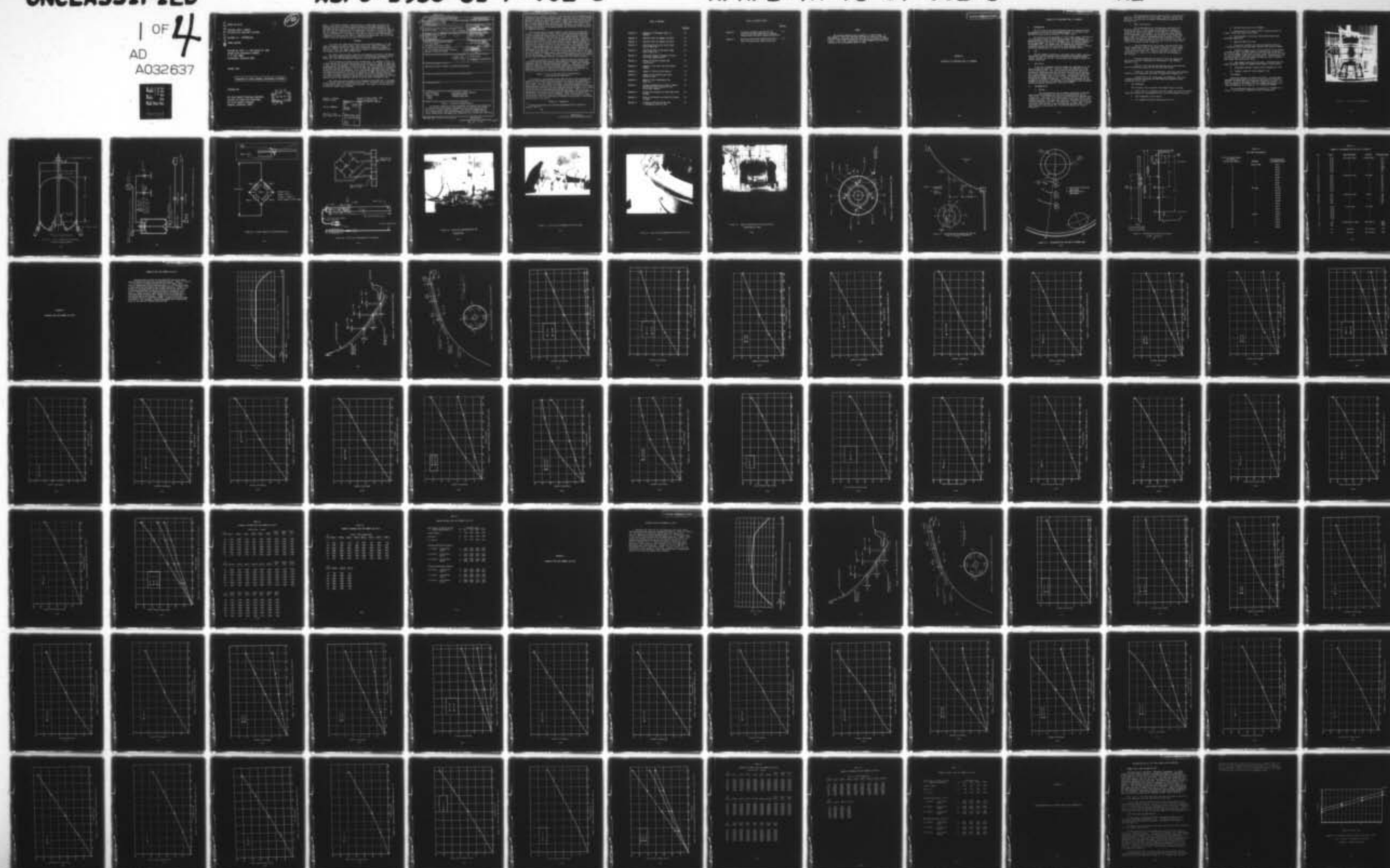

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AFRPL-TR-76-57

FLEXIBLE CASE - GRAIN IN BALLISTIC WEAPON SYSTEMS

VOLUME III - APPENDIXES

FINAL REPORT

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October 1976

Approved for Public Release; Distribution Unlimited

Prepared for:

Air Force Rocket Propulsion Laboratory
Director of Science and Technology
Air Force Systems Command
Edwards, California, 93523

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FOREWORD

This report was submitted by Aerojet Solid Propulsion Company, P. O. Box 13400, Sacramento, California, 95813, under Contract No. F04611-72-C-0055, Job Order No. 305910JU with the Air Force Rocket Propulsion Laboratory, Edwards, California, 93523. The report summarizes the technical efforts conducted under this contract from April 1972 to March 1976.

The efforts reported herein represent the combined activities of the Aerojet Solid Propulsion Company, Harold Leeming, Ph.D. and Associates, Konigsberg Instruments, Inc., the Texas A&M Research Foundation, and the University of Texas.

The key technical personnel on this program were: Mr. Kenneth W. Bills, Jr. of ASPC, who was the Principal Investigator on the Program; Mr. Samuel W. Jang, also of ASPC, who was the program's Principal Engineer; Dr. Harold Leeming, of HL&A, who coordinated the instrumentation of the motors and, later the acquisition of gage data during motor testing; Mr. Herman P. Briar, of ASPC, who conducted much of the gage diagnostic work; Mr. Eph Konigsberg, of KI, who supplied the stress and strain gages and supporting consultation; Dr. Scott W. Beckwith, of TAMRF, who provided an extensive study of flexible case materials and their constitutive relations; and Drs. Eric Becker and Robert Dunham, of the University of Texas, who developed an advanced computer code for the structural analysis of grains held in fiberglass cases.

This report has been reviewed by the Information Office/DOZ and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations. This report is unclassified and suitable for general public release.

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Project Engineer

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FOR THE COMMANDER

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Solid Rocket Division

18 19 **REPORT DOCUMENTATION PAGE**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Volume I - Technical Accomplishments

The original objective of this program was to establish the reliability of existing structural analysis techniques for the prediction of stresses and strains in solid propellant grains. This was to be accomplished by fully instrumenting a full-scale Minuteman III Stage III motor with the latest stress-strain instrumentation, subjecting it to various test conditions

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(thermal cycling, handling, vibration, pressurization) and then comparing the experimental results with predicted values. This was to be a "closed envelope" approach in which the reduced data from the gages were to be kept secret until the final assessment phase of the program. Midway through the motor testing phase serious anomalies were detected in the gage data. This led to a suspension of the original plan and an eventual redirection and change in scope to concentrate efforts on the identification and correction of the sources of the anomalies observed.

The revised program included diagnostic evaluations to isolate error sources, a system rework to correct and/or modify questionable components, a parallel laboratory investigation of specific gage characteristics and, finally, verification of the stability of the reworked system. From the results of the diagnostic tests it was determined that the major anomalies observed could be traced to the gages-lead-wire-solder junction combinations. Use of an acid flux in soldering the stainless steel leadwires provided a potential for corrosion to occur as the junction aged. The reworked system, which included crimped spade-lug junctions in place of the leadwire solder joints, a new DAS and revised operational procedures showed a substantial improvement in system stability, exhibiting an average drift rate of 0.5% of full scale output per month. This value is consistent with that for the gages alone as quoted by the manufacturer, and converts to about 0.75 psi per month for the 150 psi gage. However, this drift is considered excessive for measurement of long term thermal stresses (as required by the original program).

Laboratory evaluations of the gages addressed potential problems associated with exposed semi-conductor strain gages on the normal stress gage diaphragm, gage self-heating and hysteresis effects. These tests indicated potential transducer response differences between the calibration and the high rate pressurization situations which would require experimentally determined corrections to achieve the accuracy required to accomplish the original program goals for the high rate pressurization tests.

Volume II - Solid Propellant Grain Instrumentation
System Design and Application

The experience and knowledge gained from this and similar programs were compiled in this volume, which was designed as a guide to the experimental stress analysis of solid propellant grains. The effort was divided into six major phases. The first phase is directed to the program manager and the project engineer, who must make the initial decision to conduct such an effort. The second and third phases are more elaborate versions of Phase I, but involve realistic plans for instrumenting and testing the units. Phase III is an evaluation of these plans to assure that the measurements can be obtained with the available facilities and test equipment. Phases IV and V define the extensive work required to carry out the test plans, while Phase VI includes the reduction of the test data and an assessment of the quality of the testing and the value of the results.

Volume III - Appendices

Seventeen appendices give detailed supplemental data in support of Volumes I and II.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

FORMAT

The attached appendixes were prepared in a simple format. In each appendix a brief text explains the nature of the work, the test results and any relevant conclusions that may not be covered in Volumes I and II. All of the illustrations of a given appendix are given next, followed by the corresponding tables of data.

APPENDIX A

HYDROTESTS OF MINUTEMAN STAGE III CHAMBERS

HYDROTESTS OF MINUTEMAN STAGE III CHAMBERS

A. INTRODUCTION

The first step in the motor fabrication and test program involved the hydrotest of the full scale Minuteman chambers to characterize the deformation versus pressure response of the motor cases.

The first full scale Minuteman III, Third Stage chamber (S/N 30113-1), a 52-inch diameter glass filament wound structure, was hydrotested to a maximum pressure of 200 psi on 25 September 1972. The second Minuteman III, Third Stage chamber (S/N 30114-1) was hydrotested the following week on 29 September 1972. The chambers were instrumented and hydrotested in accordance with AGC Test Plan 1826-26-TP, dated September 1972, to measure strains and deflections as a result of internal pressure effects.

B. TEST

The two chambers, identified as S/N 30013 and S/N 30014, purchased from Thiokol, were of ASPC design and conformed to AGC Drawing Numbers 1147251, 1147250, and 1147278. They had been proof tested to 720 psi by Thiokol Corporation.

C. TEST SET-UP

In the test arrangement used the chamber was supported by its aft skirt as shown in Figure A-1. Figure A-2 shows the hydrotest tooling (P/N 1017623) installed. This tooling reduces the pressure load on the aft dome by transferring that part acting on the piston to the forward skirt, thus simulating the firing test load. A high pressure water pump was connected through a port in the piston of the hydrotest tooling to pressurize the chamber (Figure A-3). A complete listing of the tooling and materials required for hydrotest, plus a detailed procedure for the assembly of the tooling, are contained in the documentary files (Minuteman Production Standard Procedure No. 113A) sent to AFRPL.

D. INSTRUMENTATION

1. General

The instrumentation used to measure deflections of the motor cases during the hydrotests were cantilever beam-deflection devices (Figure A-4). These deflection devices were fabricated by mounting four conventional strain gages, B.L.H type FAB-25-12, onto the .030 inch thick tempered steel beam. The gages were located at the highest stress point to provide maximum sensitivity. Two gages (Nos. 1 and 2, Figure A-4) were installed on the top side of the steel beam and two gages (Nos. 3 and 4) were installed on the bottom side. Fabrication details are shown in Figure A-5.

The instrumentation used to measure strain in the aft dome consisted of conventional foil strain gages. They were the BLH type FAB-25-12. The gages used to measure circumferential growth were the BLH type PA-52.

2. Motor Installations

The instrumentation for the hydrotests consisted of 25 deflection devices, 11 strain gages, and two pressure transducers. The deflection devices were mounted on one side to a rigid external framework and then to the chamber. Six of these units were located in the forward dome area and three were installed in the forward boss area, Figure A-6. Similar instrumentation was installed in the aft chamber area to measure aft dome and aft closure deflections, Figure A-7. Additionally, six deflection devices were used to measure longitudinal growth in the barrel section, Figure A-8.

Three circumferential strain gages, BLH type PA-52, were used to measure hoop strain in the barrel, Figure A-9. Eight conventional strain gages, BLH type FAB-25-12, were used to measure strain in the aft head, Figure A-10. They were installed at an angle of approximately 23°, which is the angle of wrap for the fiberglass in the aft head.

Pressure transducers were placed at both the forward and aft closures and were independent of the pressure in the incoming hydraulic lines.

Table A-1 lists the code designations used to correlate the test plan numbering system with the Test Area code system.

Table A-2 lists the instrumentation used during the hydrotests. Locations of instrumentation are shown in Figures A-10 through A-13.

Installation of the strain gages and deflection reeds were standard operational procedures for ASPC (they are contained in the documentary files, also).

E. TEST PROCEDURES

The procedures used to hydrotest the chambers were as follows:

1. Verify that all transducers and strain gages are installed properly. Range and calibrate all instrumentation prior to filling chamber with water.

2. Take photographs of test setup.

3. Fill chamber with water and bleed out all air.

4. Perform visual leak test of chamber.

5. Pressurize with city water to 55 $\pm$ 5 psig and return to 0 psig. Verify that there are no leaks.

6. Verify chamber is at 0 psig, then perform balance and calibration operations.

7. Make sure pumps are ready.

8. Turn on all recorders and with oscillograph running at .1 inches per second using city water, perform final bleed of chamber.

9. Pressurize chamber case to 50 psig and hold for 60 seconds to record all data. Increase pressure in 50 psig steps to 200 psig, hold for 60 seconds at each step to record all data and return to 0 psig in a similar manner, recording at each hold point. Pressurization rise and decay rates will be in the order of minutes per step, to achieve good steady state calibration levels.

10. Vent chamber system and drain water. (Precaution must be taken to prevent collapse of chamber during removal of test fluid).

11. Disassemble hydrotest tooling as per Procedure No. 113A.

12. Prepare a report of tooling damage if any.

F. TEST RESULTS

During the hydrotest of Chamber S/N 30114-1, two minor leaks developed at approximately 150 psig, near the middle of the barrel section. The leaks were water "weeping" through the case wall. All leaks discovered in the hydrotest of this chamber were marked on the case and documented in an historical I.R. (Inspection Report).

The case deflection data for the hydrotests of Chambers No. 1 and No. 2 are contained in Appendices B and C,respectively.

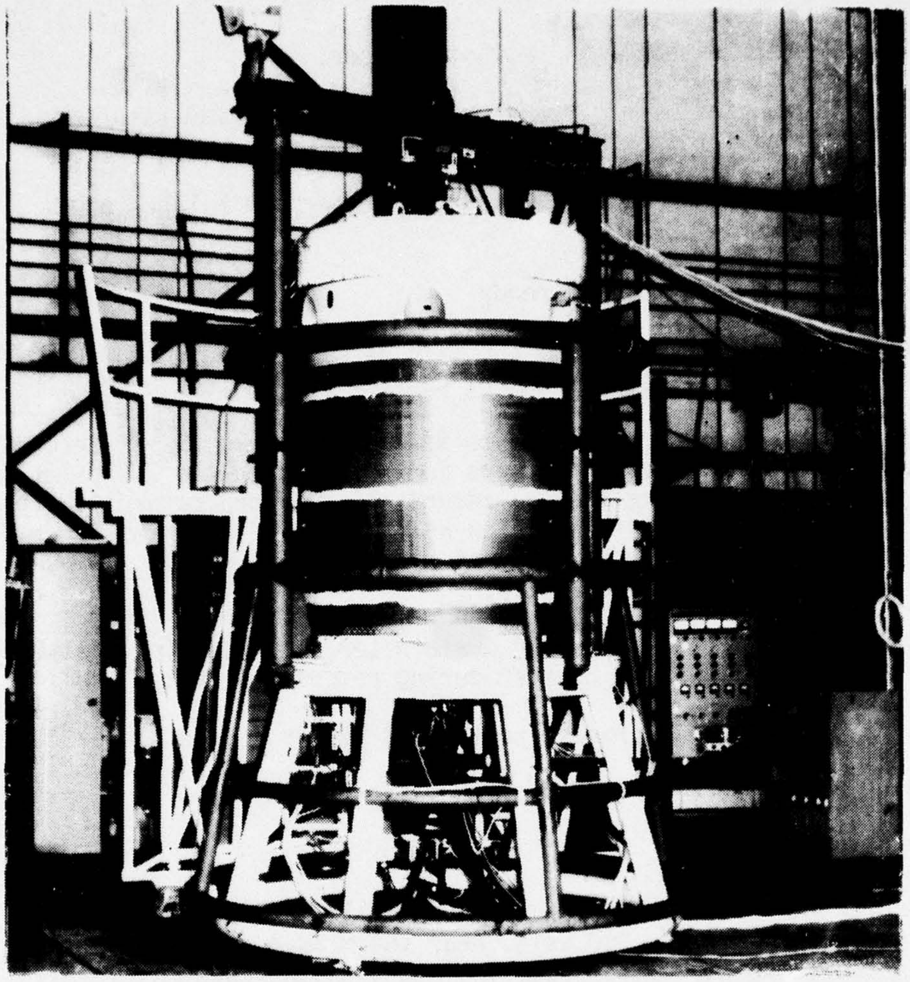


FIGURE A-1. TEST SET-UP FOR HYDROTESTS

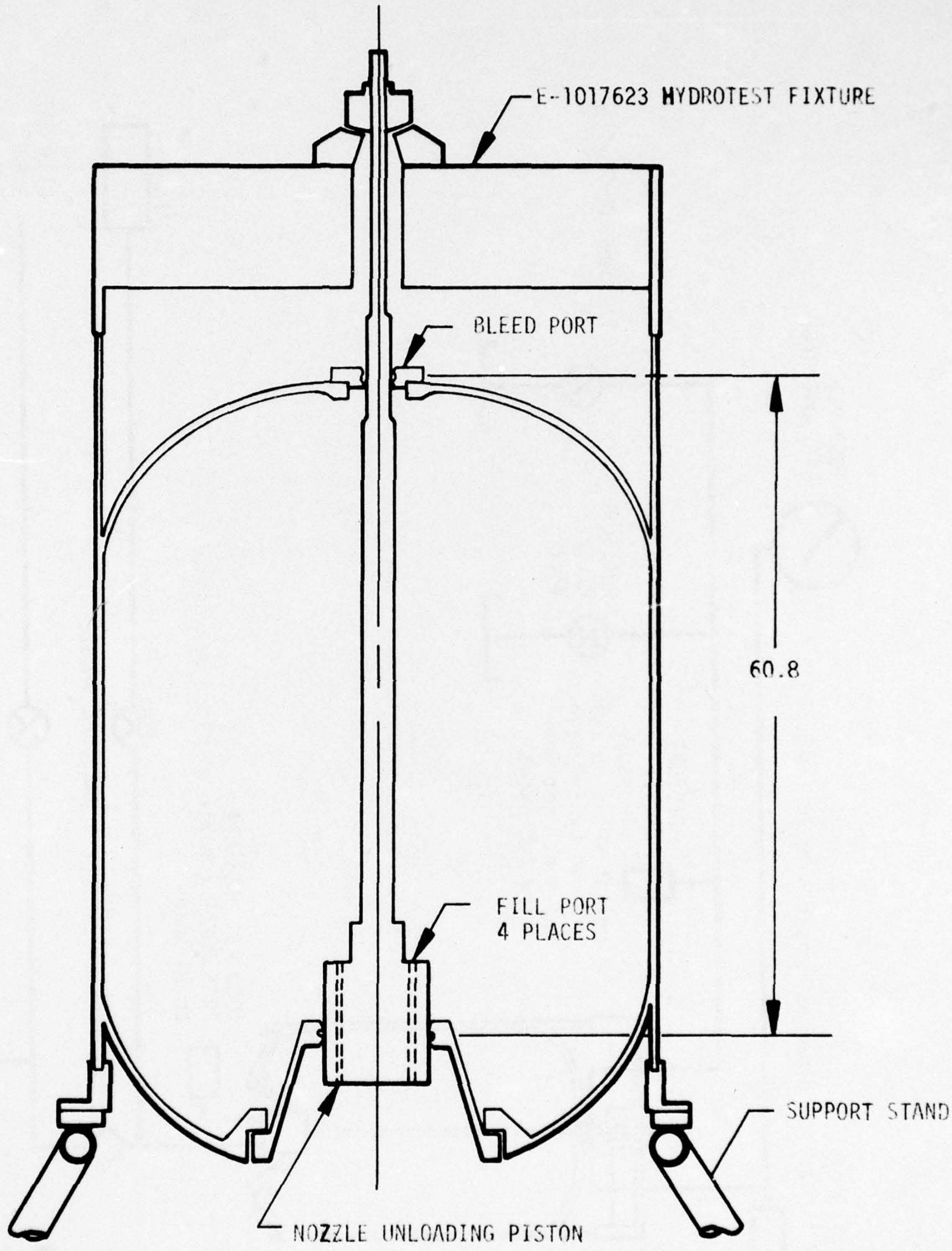


FIGURE A-2. SKETCH OF MOTOR WITH SUPPORTING EQUIPMENT DURING HYDROTEST

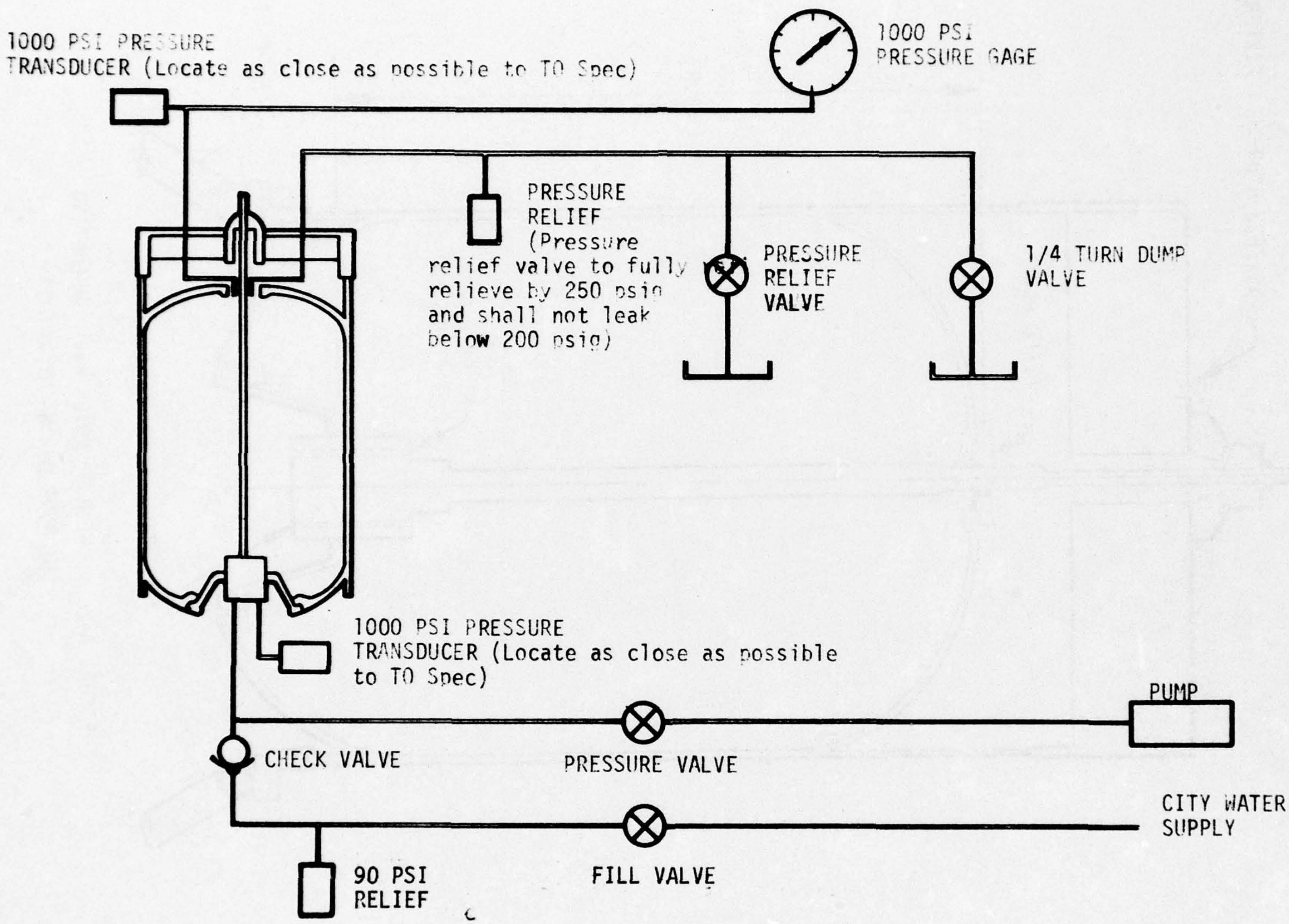


FIGURE A-3. SCHEMATIC OF FULL-SCALE MOTOR HYDROTEST SETUP

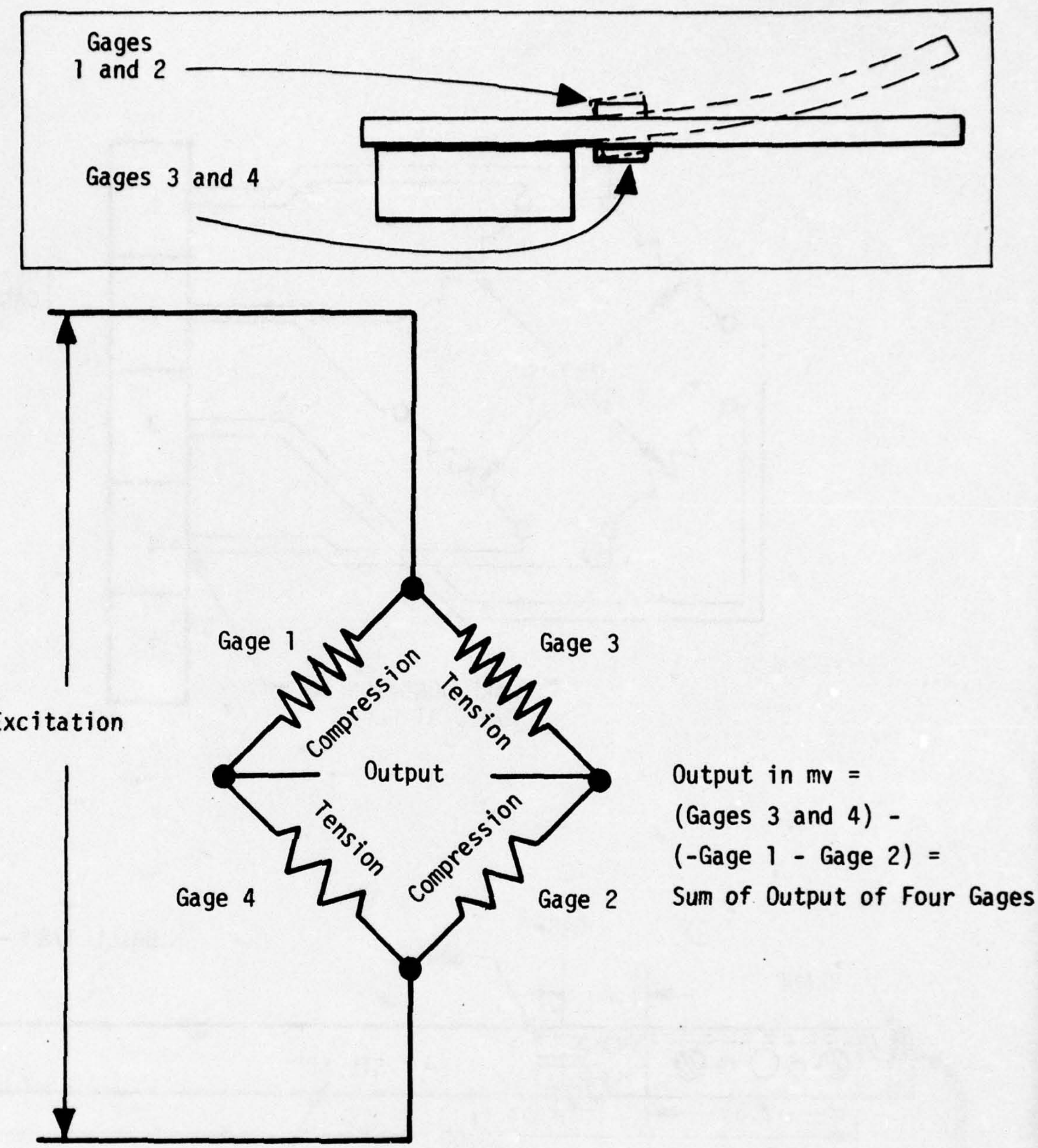


FIGURE A-4. CIRCUIT ANALYSIS OF DEFLECTION DEVICE

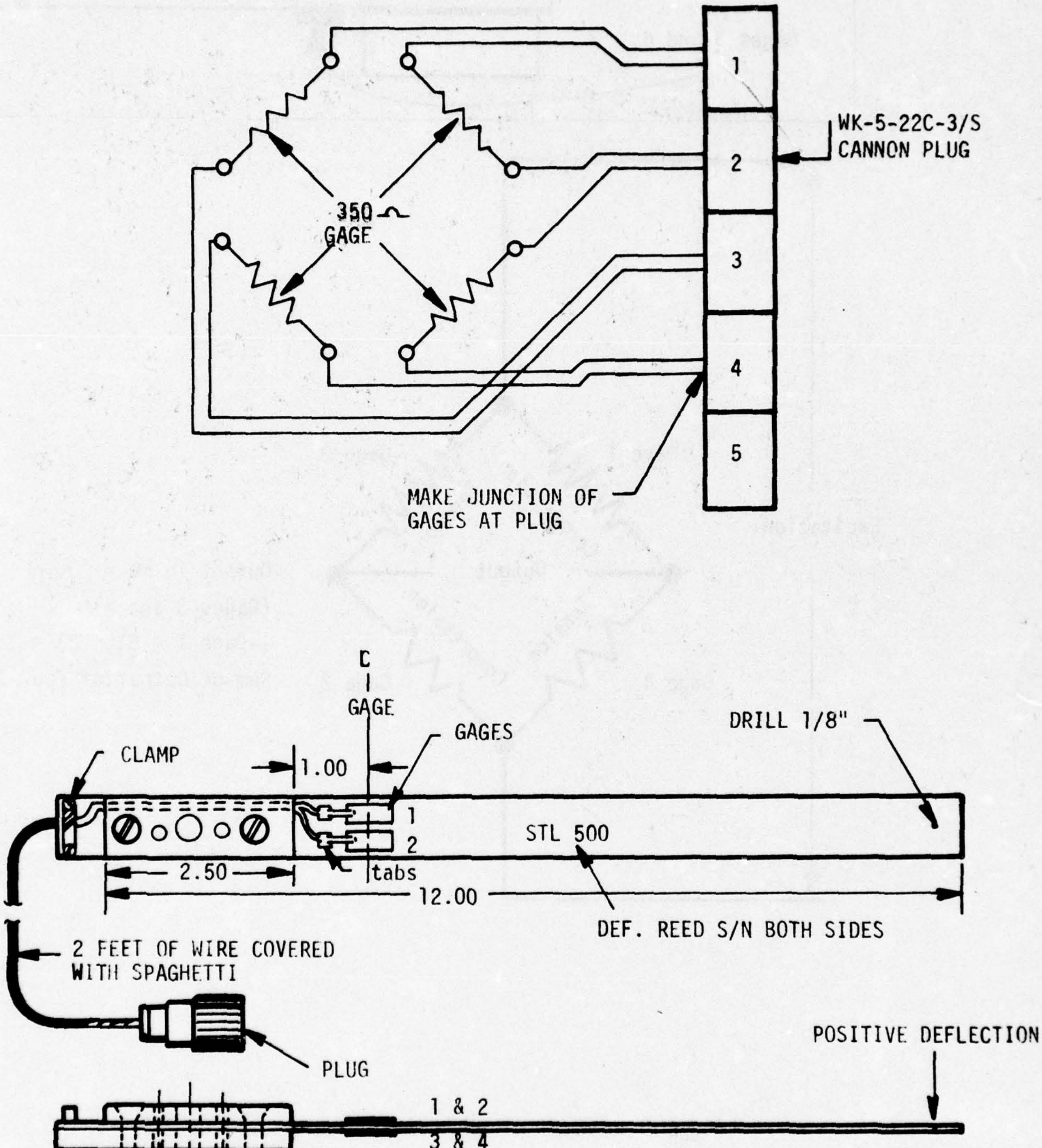


FIGURE A-5. DEFLECTION REED (FABRICATION PROCEDURE)

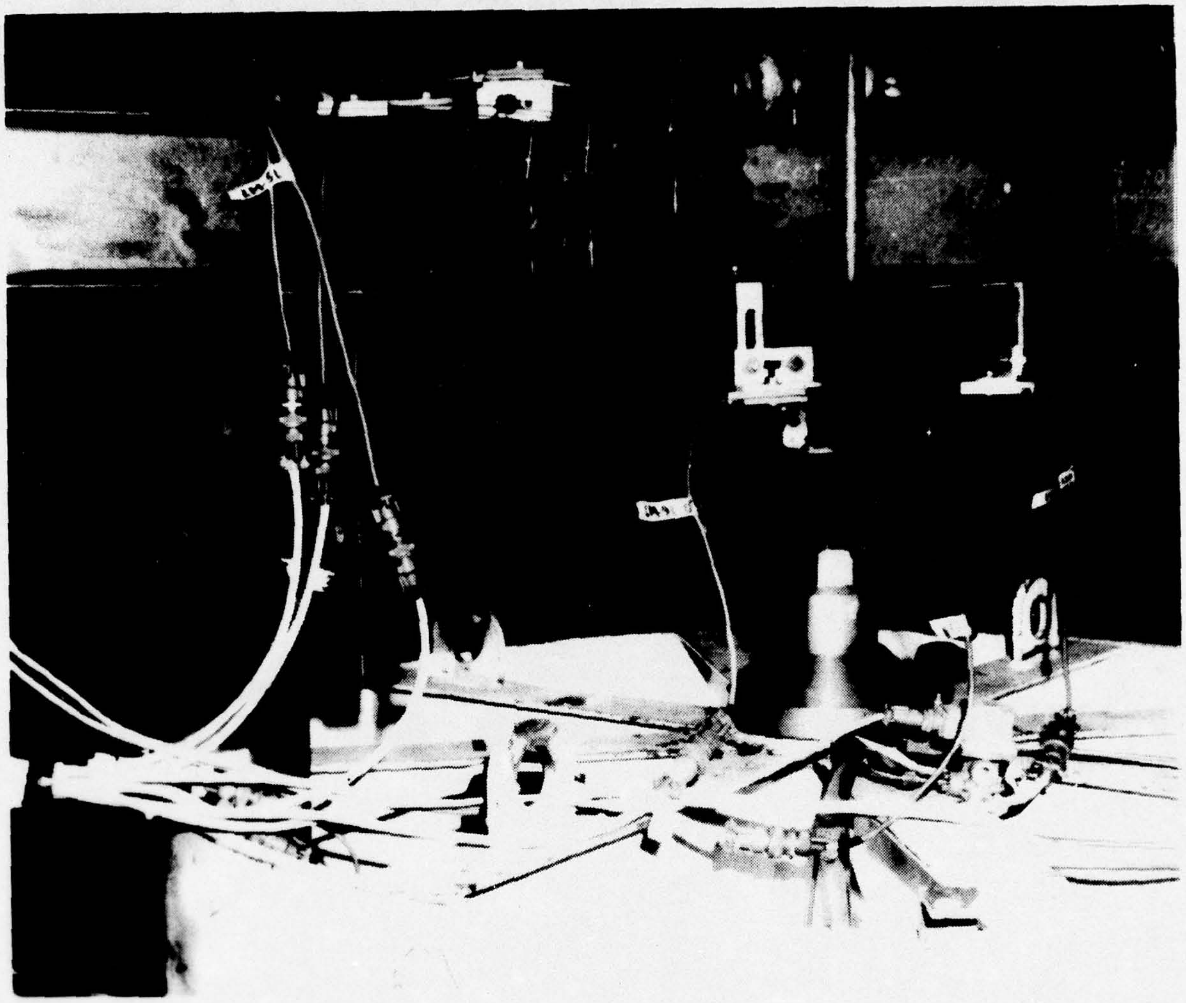


FIGURE A-6. DEFLECTION INSTRUMENTATION FOR FORWARD DOME

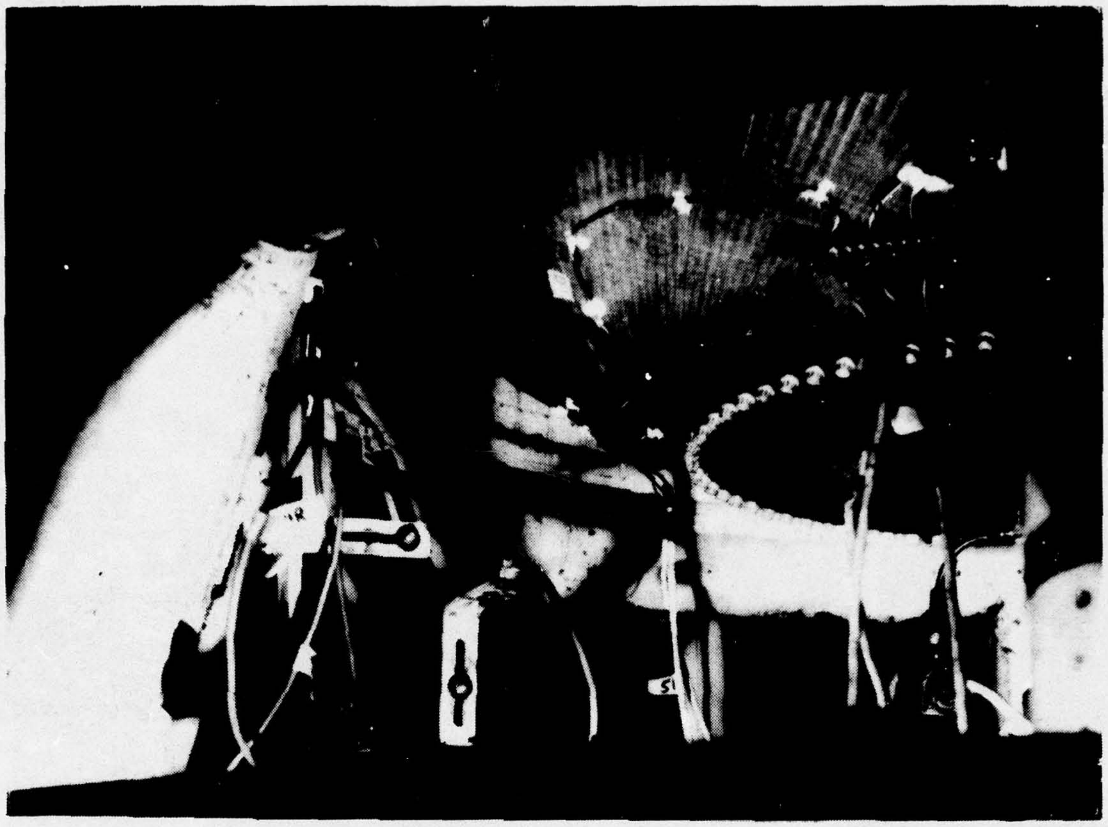


FIGURE A-7. DEFLECTION INSTRUMENTATION ON AFT DOME

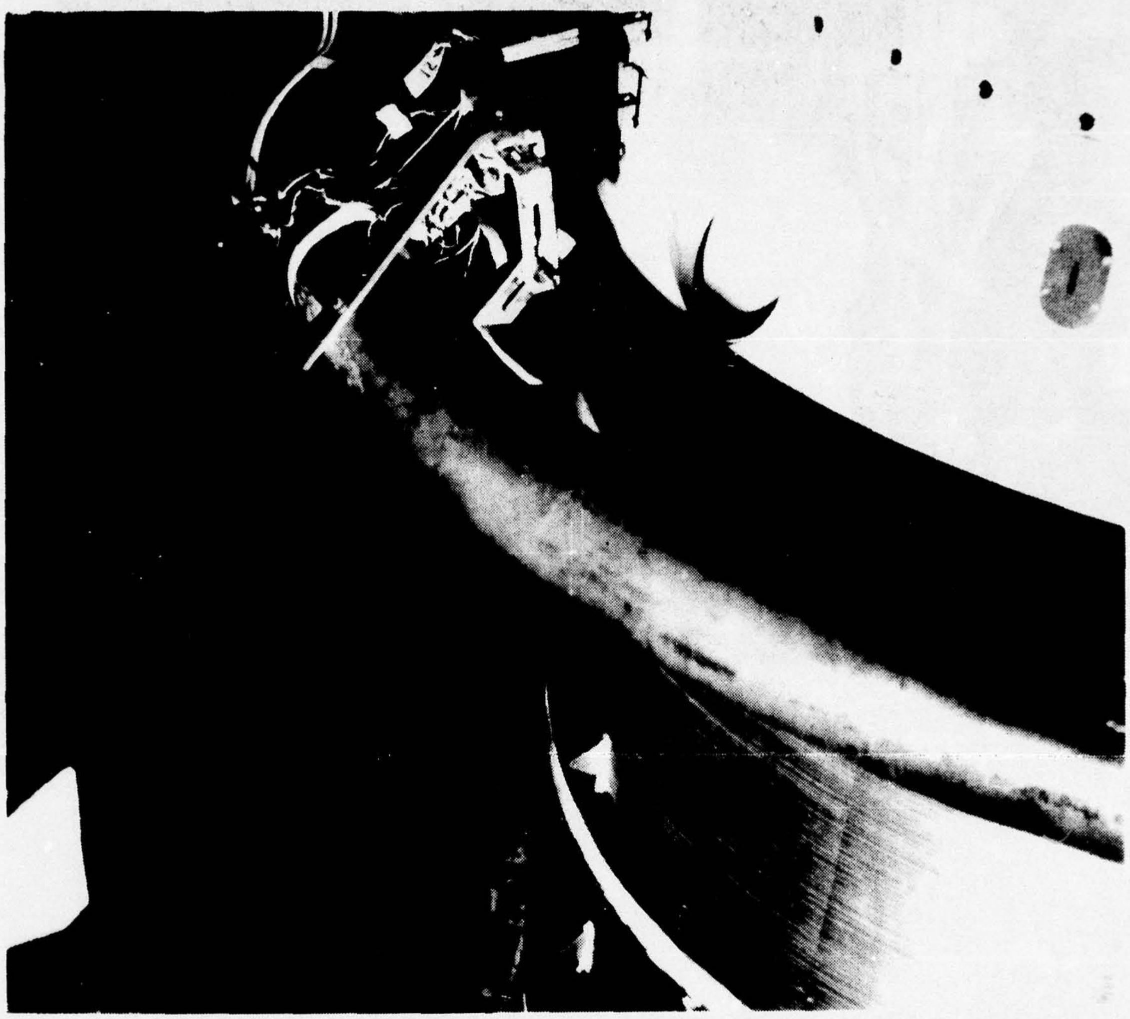


FIGURE A-8. DEFLECTION INSTRUMENTATION FOR BARREL SECTION

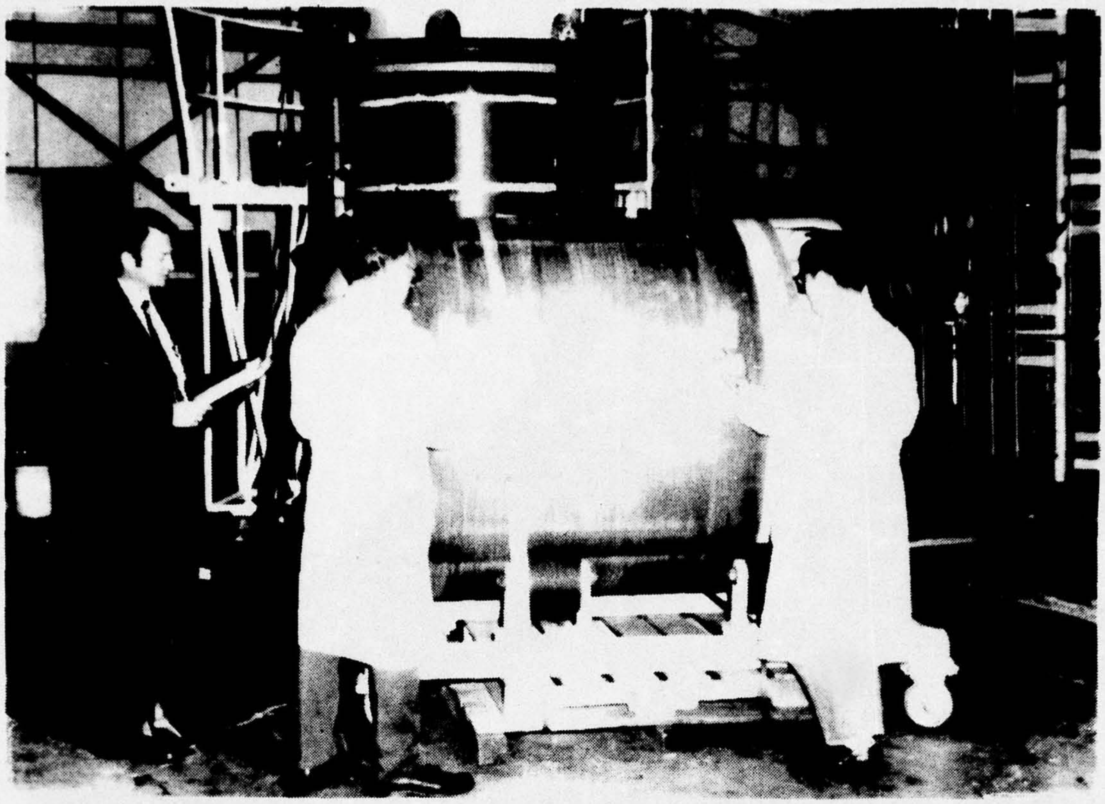


FIGURE A-9. SURFACE PREPARATION FOR INSTALLATION OF CIRCUMFERENTIAL GAGES

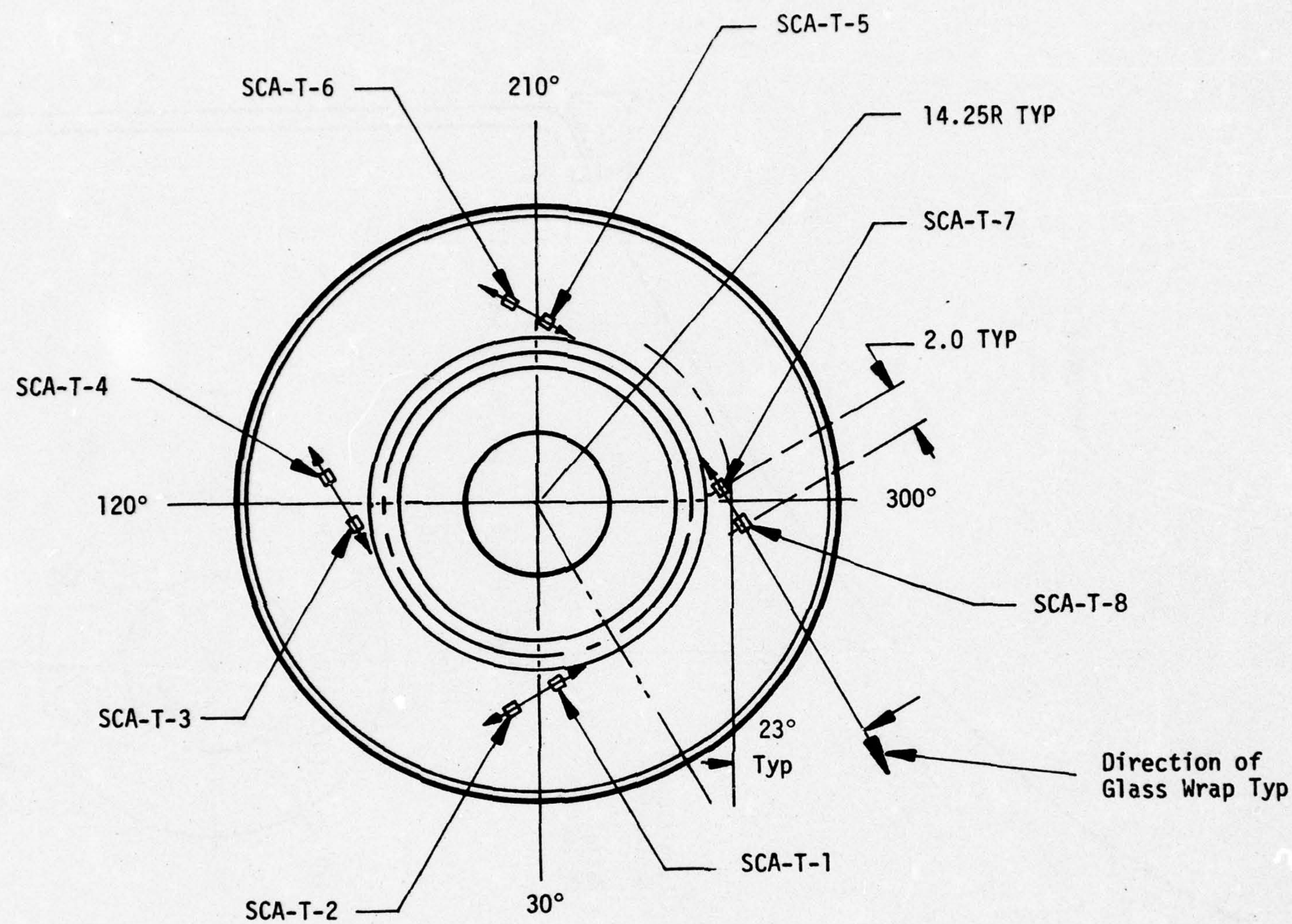


FIGURE A-10. INSTRUMENTATION LOCATIONS ON AFT DOME

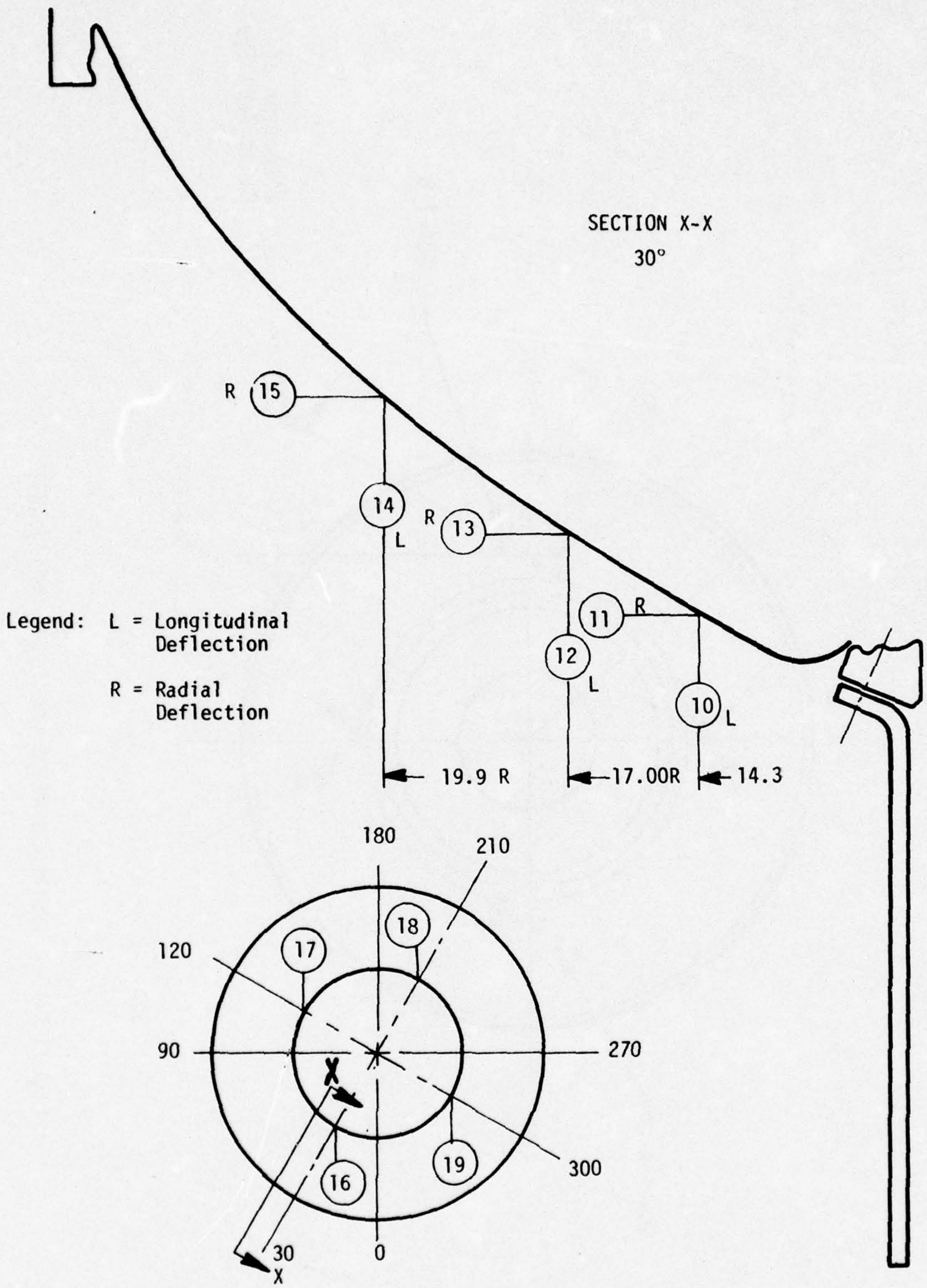


FIGURE A-11. INSTRUMENTATION LOCATIONS ON AFT DOME AND BOSS FOR DEFLECTION MEASUREMENTS

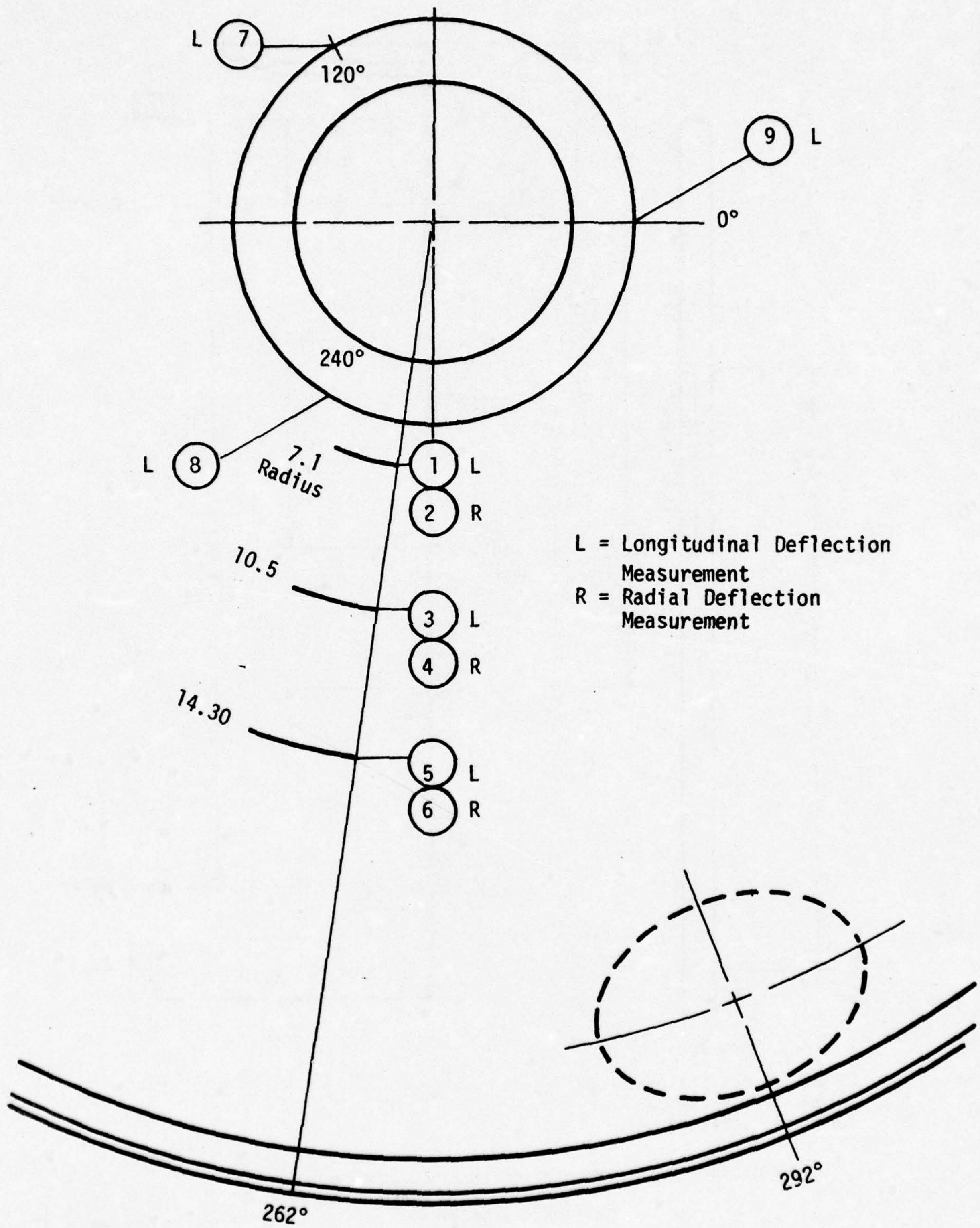
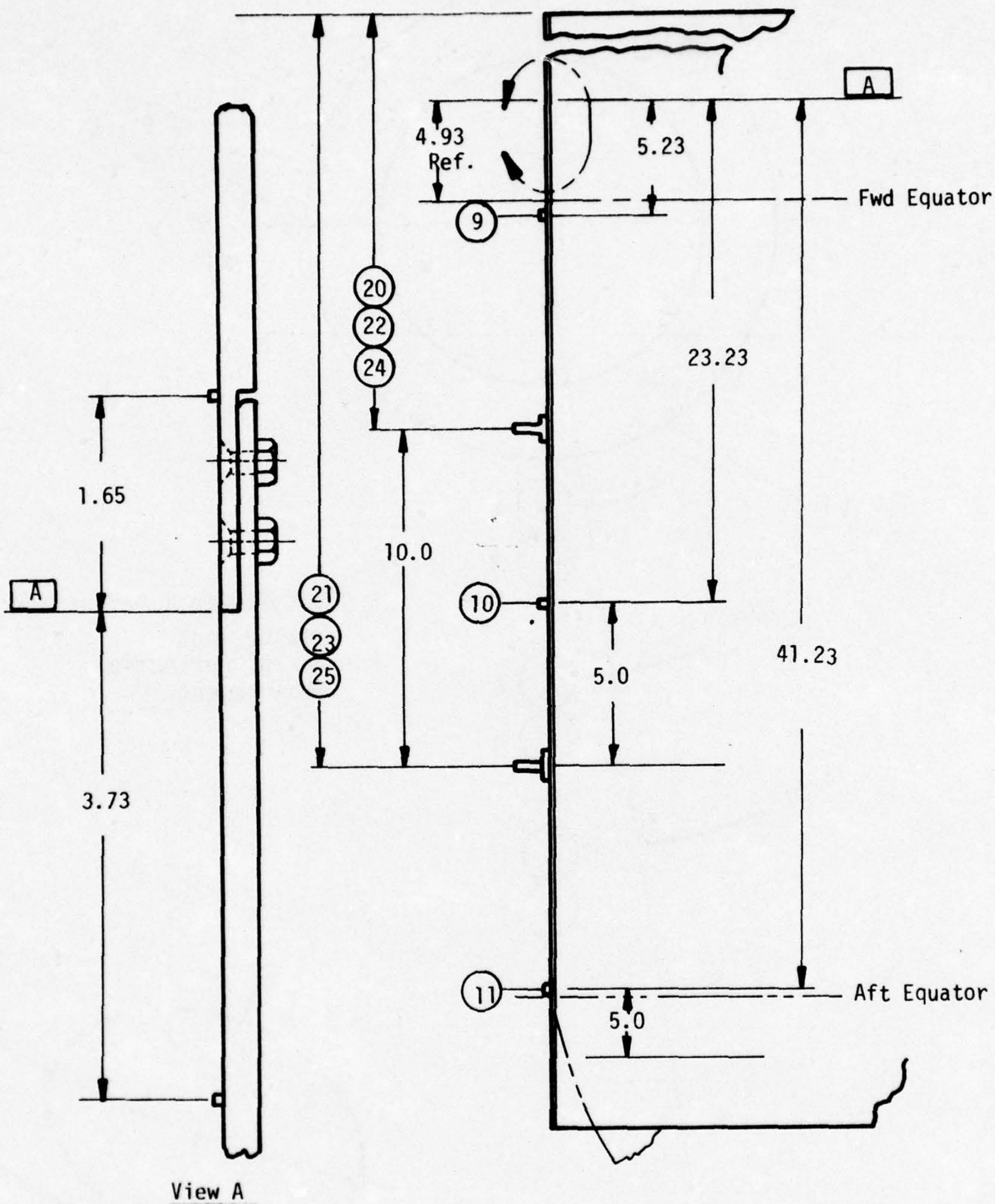


FIGURE A-12. INSTRUMENTATION LOCATIONS ON FORWARD DOME



20-25 are deflections,
9, 10, 11 are circumferential strain gages.

FIGURE A-13. INSTRUMENTATION LOCATIONS ON CYLINDER

SECTION - SECTION 45°

TABLE A-1

TEST CODE RELATIONSHIPS

External Growth Channel Designation (As per Test Plan)	Location	Code Designations of Plotted Curves
1	Forward Dome	LM-1L
2	"	LM-2R
3	"	LM-3L
4	"	LM-4R
5	"	LM-5L
6	"	LM-6R
7	"	LM-7L
8	"	LM-8L
9	"	LM-9L
10	Aft Dome	LM-10L
11	"	LM-11R
12	"	LM-12L
13	"	LM-13R
14	"	LM-14L
15	"	LM-15R
16	"	LM-16
17	"	LM-17
18	"	LM-18
19	"	LM-19
20	Barrel	LM-20
21	"	LM-21
22	"	LM-22
23	"	LM-23
24	"	LM-24
25	"	LM-25

TABLE A-2

SUMMARY OF INSTRUMENTATION FOR 200 PSI HYDROTEST

No.	Figure	Type Transducer	Location	Estimated Range
1	A-12	Deflection Reed	Forward Dome	.4 in.
2	A-12	"	"	.03
3	A-12	"	"	.35
4	A-12	"	"	.035
5	A-12	"	"	.25
6	A-12	"	"	.036
7	A-12	"	"	.0466
8	A-12	"	"	.46
9	A-12	"	"	.48
10	A-11	Deflection Reed	Aft Dome	.23
11	A-11	"	"	.08
12	A-11	"	"	.2
13	A-11	"	"	.08
14	A-11	"	"	.15
15	A-11	"	"	.08
16	A-11	"	"	.32
17	A-11	"	"	.32
18	A-11	"	"	.32
19	A-11	"	"	.32
20	A-9	Deflection Reed	Barrel	-.04
21	A-9	"	"	-.08
22	A-9	"	"	-.04
23	A-9	"	"	-.08
24	A-9	"	"	-.04
25	A-9	"	"	-.08
1	A-10	Strain Gage	Aft Head	
2	A-10	"	"	
3	A-10	"	"	
4	A-10	"	"	
5	A-10	"	"	
6	A-10	"	"	
7	A-10	"	"	
8	A-10	"	"	
9	A-9	Circumferential Gage	Gage Barrel	3000
10	A-9	"	"	5400
11	A-9	"	"	3000
1	A-3	Pressure	Aft Closure	1000
2	A-3	Pressure	Fwd Closure	1000

APPENDIX B

HYDROTEST DATA FOR CHAMBER S/N 30113

HYDROTEST DATA FOR CHAMBER S/N 30113

Tabulated data and plots of case deflection and strain versus internal pressure are given for each measuring device. Tables B-1 and B-2 list the data of the deflection devices and strain gages, while Table B-3 summarizes the more pertinent data; i.e., of the hoop strains in the barrel, and the forward and aft dome deflections. Graphic illustrations of the hoop strains in the cylinder section and the aft and forward dome deflections at 200 psig are shown in Figures B-1, B-2, and B-3. Figures B-4 to B-9 show the curves for the forward head deflection versus pressure, while Figures B-10 to B-16 show the aft head deflections versus pressure. Figures B-17 to B-19 show the longitudinal strain in the barrel section. Figures B-20 to B-27 show the strains in the aft head. Figure B-28 presents the circumferential growth of the case with chamber pressurization.

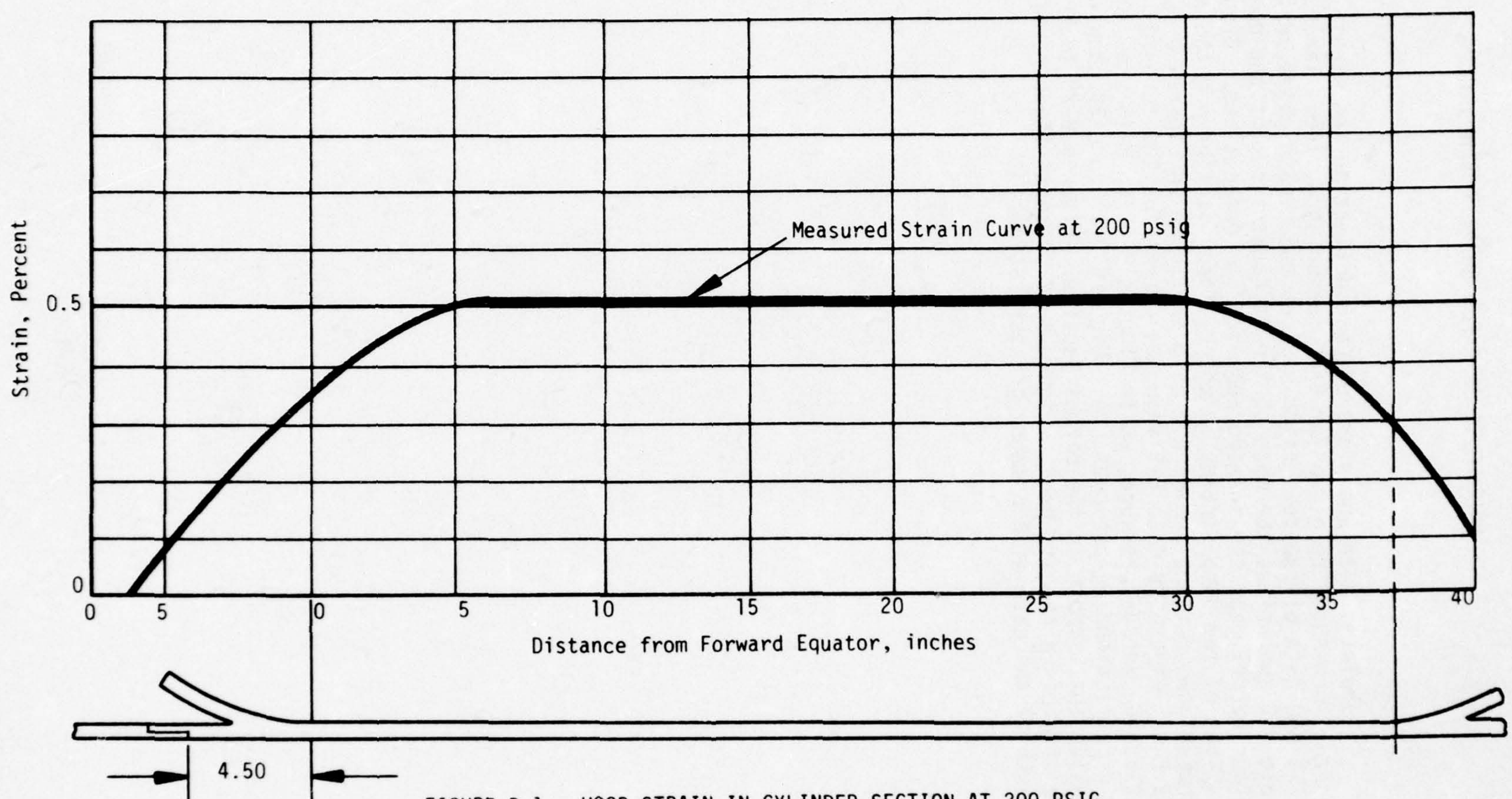


FIGURE B-1. HOOP STRAIN IN CYLINDER SECTION AT 200 PSIG

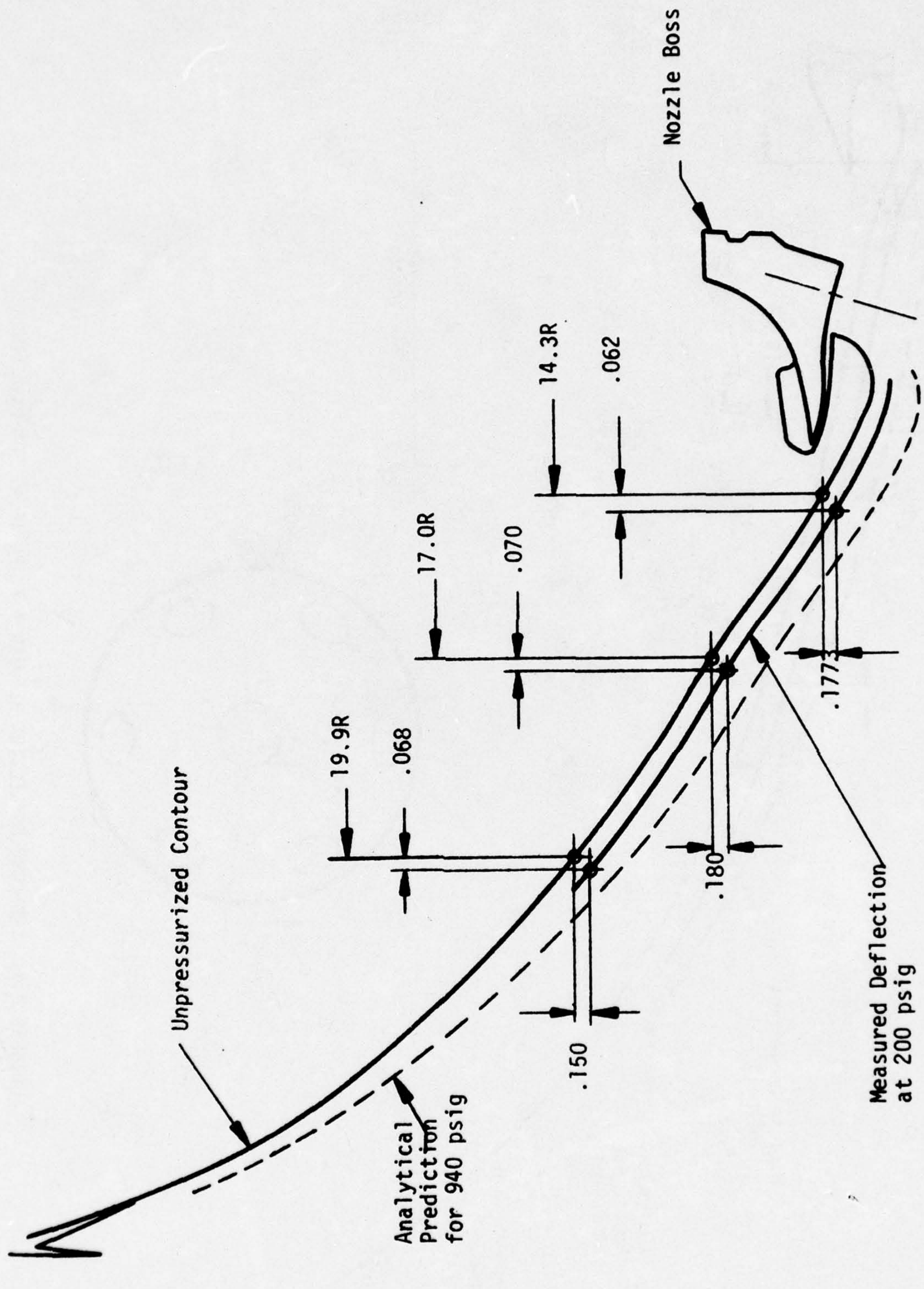


FIGURE B-2. AFT DOME DEFLECTION AT 200 PSIG (INCHES)

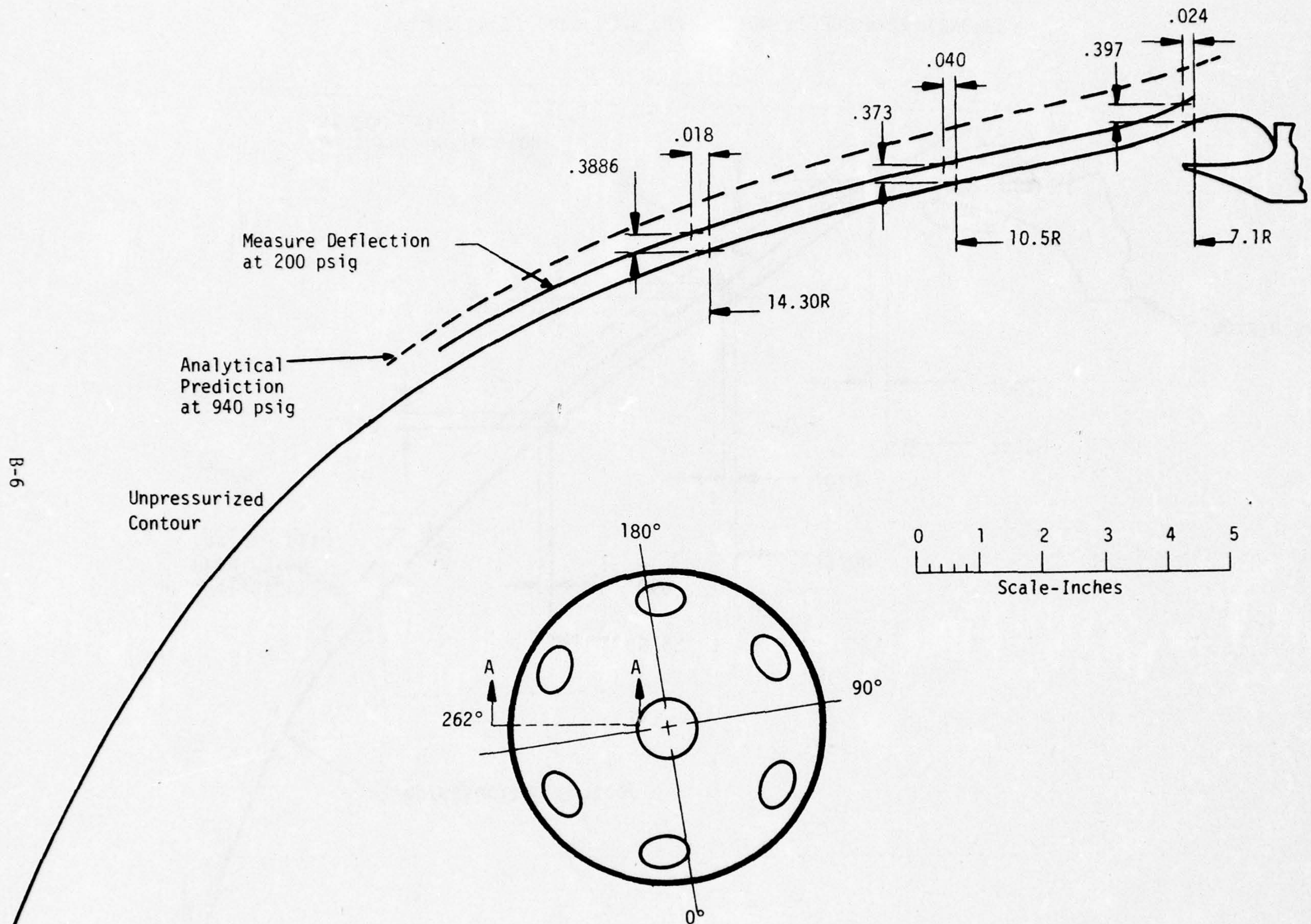


FIGURE B-3. FWD DOME DEFLECTION BETWEEN T.T. PORTS AT 200 PSIG (INCHES)

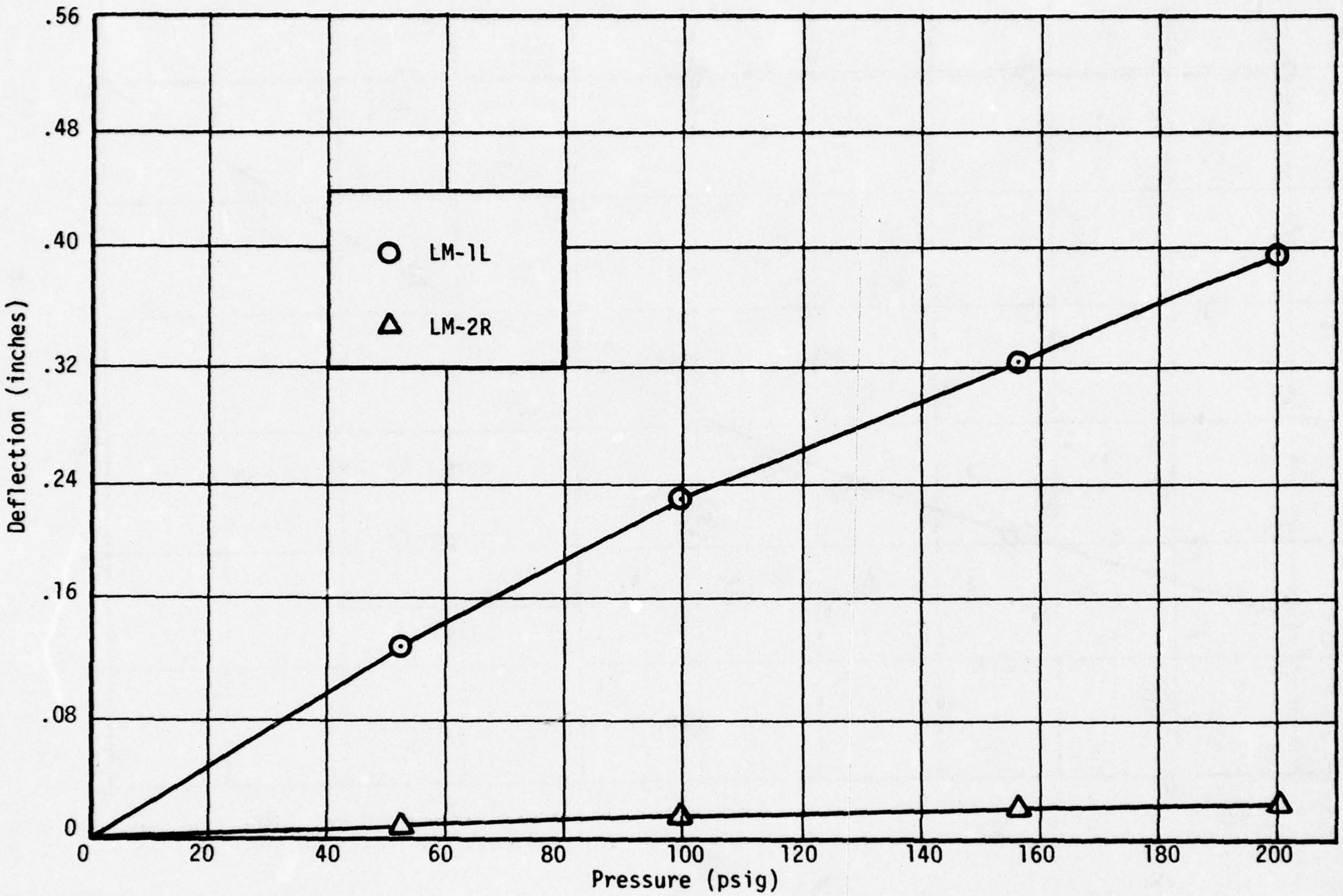


FIGURE B-4. DEFLECTION VS PRESSURE FOR DEVICES LM-1L & LM-2R

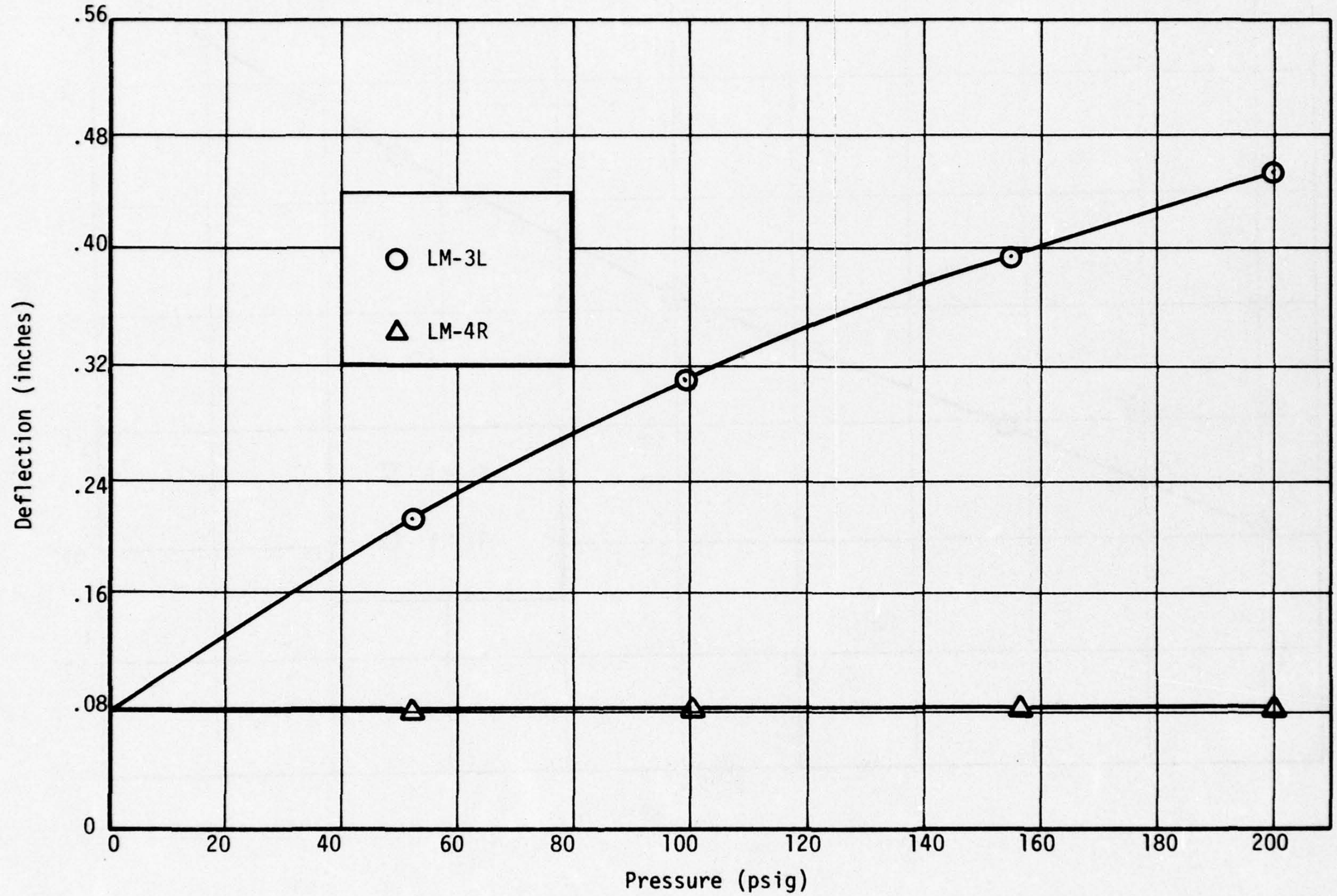


FIGURE B-5. DEFLECTION VS PRESSURE FOR DEVICES LM-3L & LM-4R

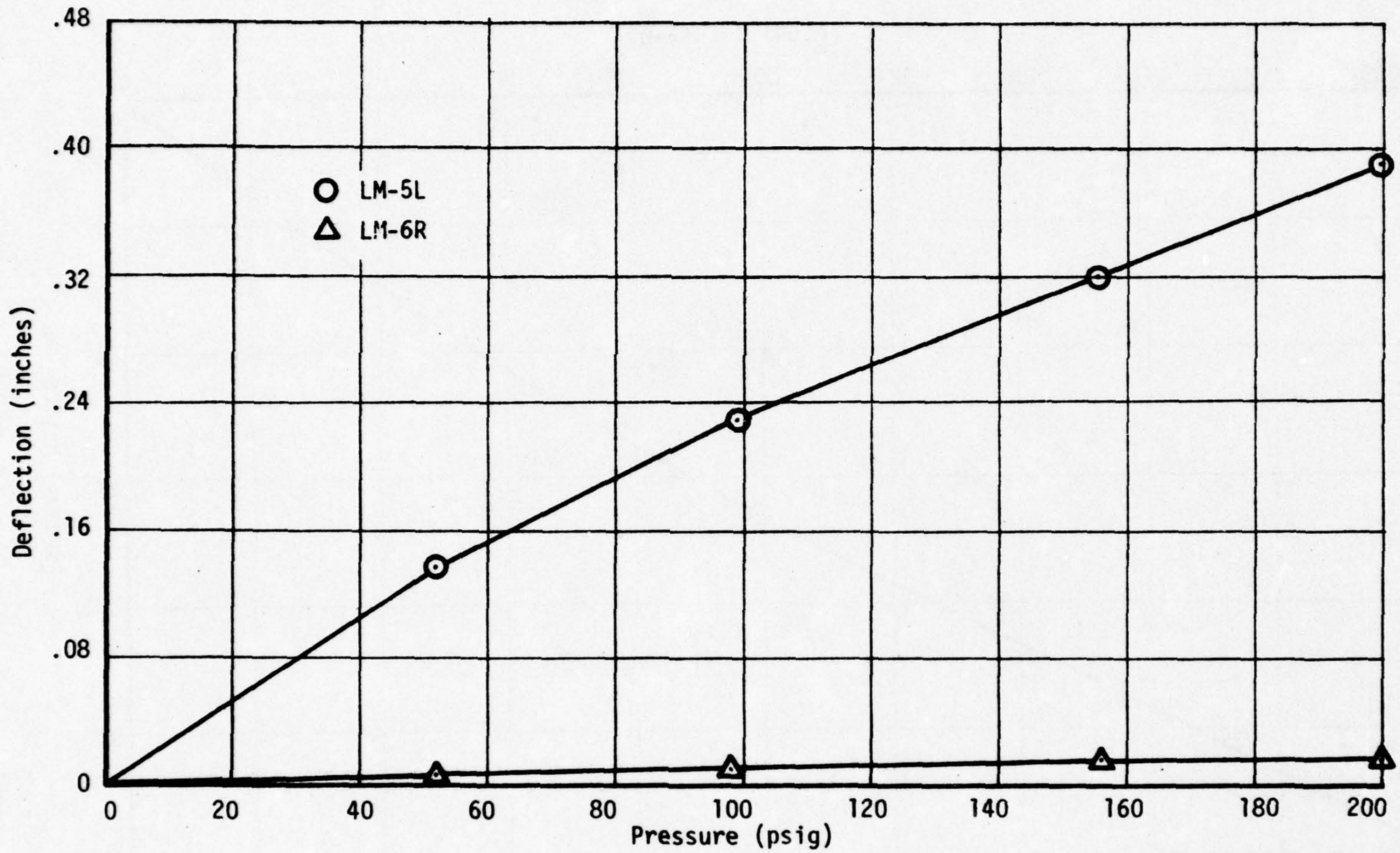


FIGURE B-6. DEFLECTION VS PRESSURE FOR DEVICES LM-5L & LM-6R

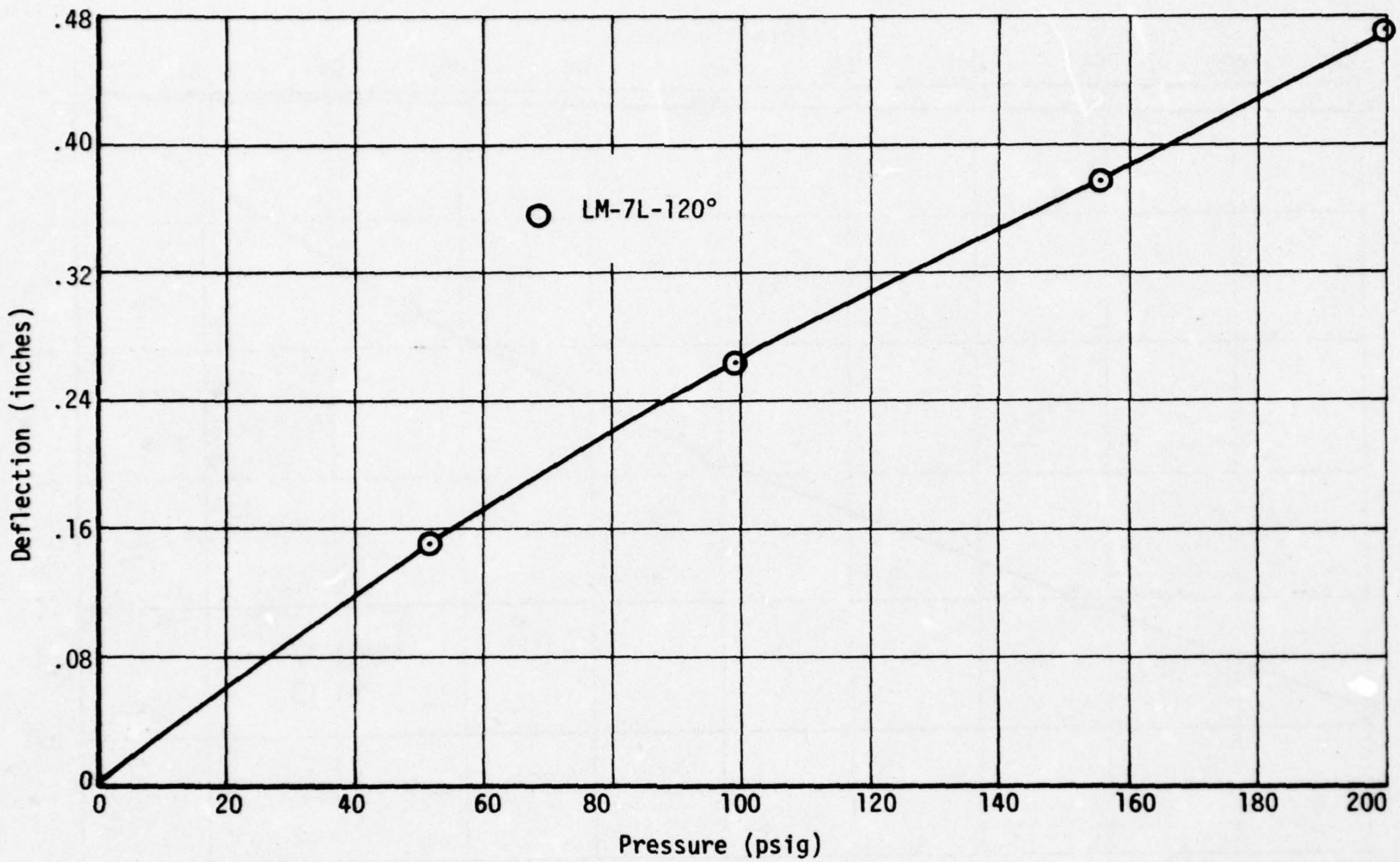


FIGURE B-7. DEFLECTION VS PRESSURE FOR DEVICE LM-7L

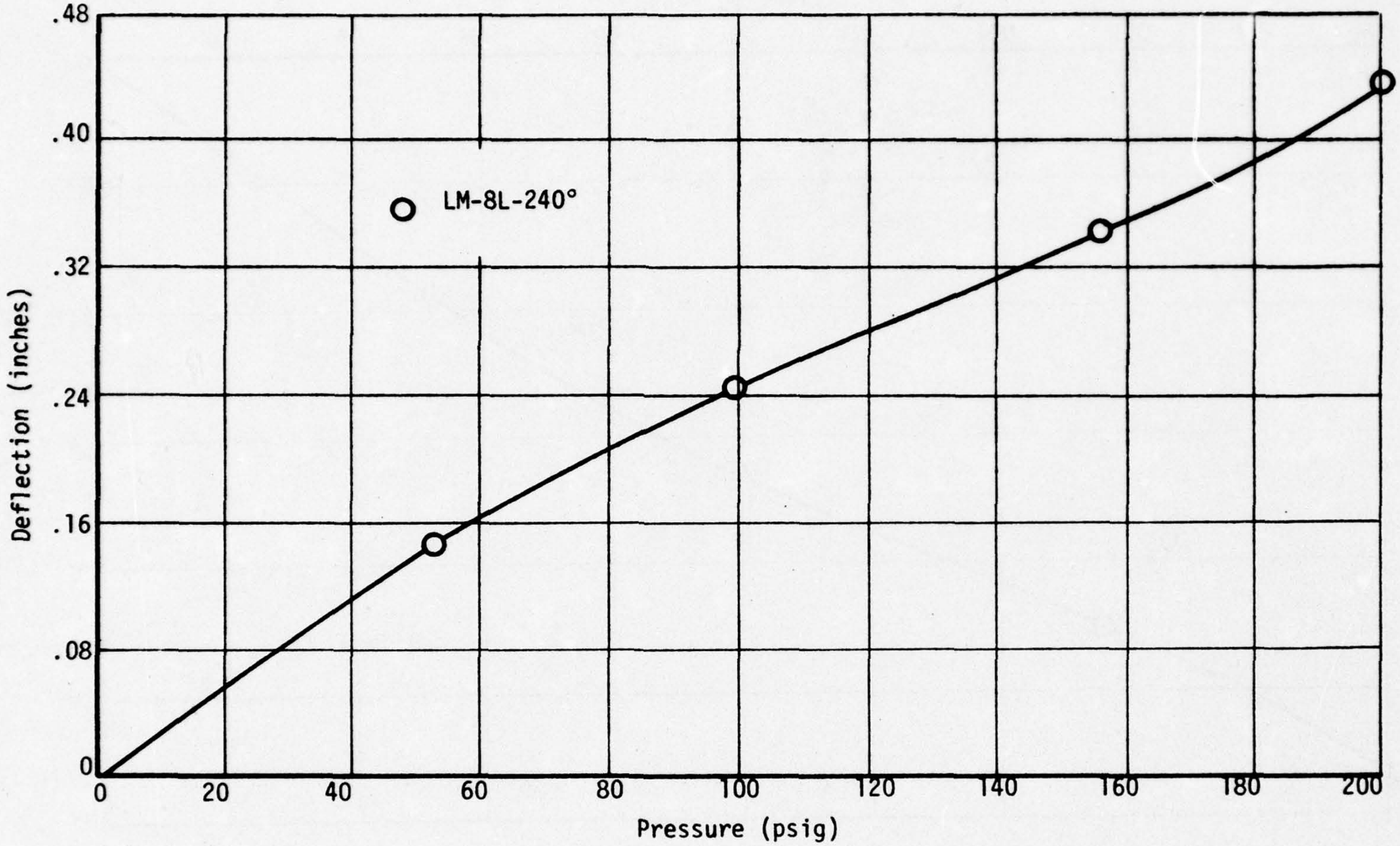


FIGURE B-8. DEFLECTION VS PRESSURE FOR DEVICE LM-8L

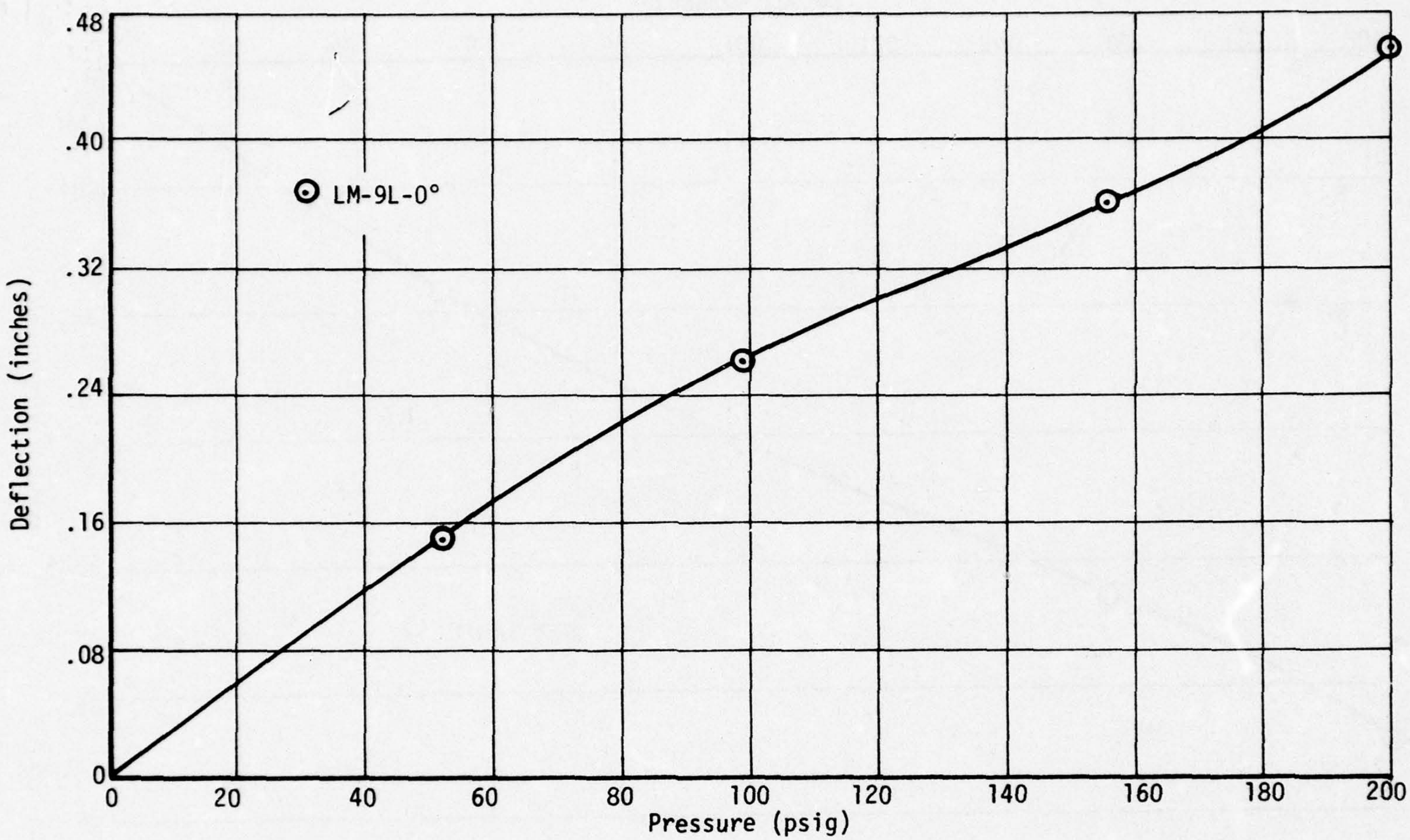


FIGURE B-9. DEFLECTION VS PRESSURE FOR DEVICE LM-9L

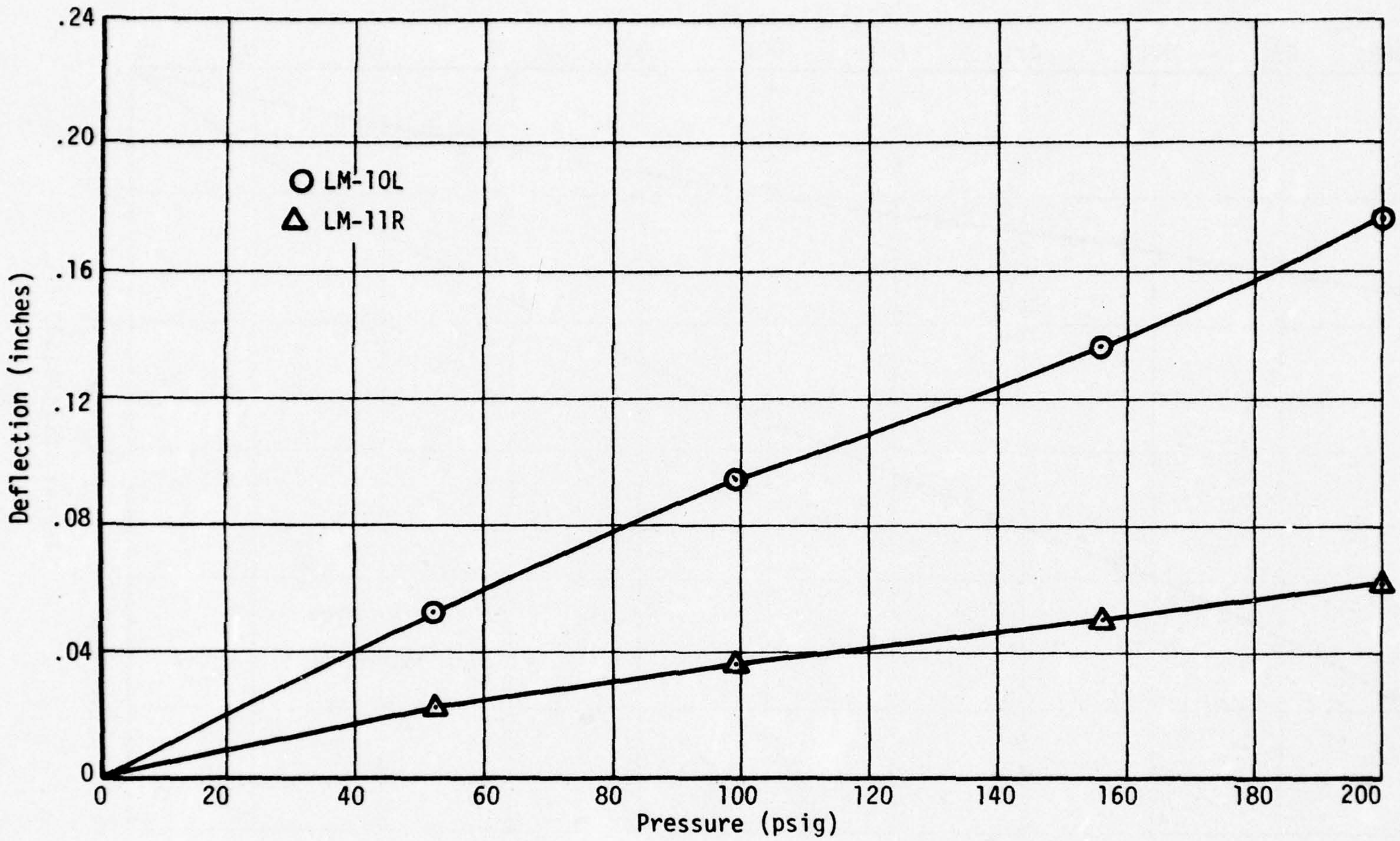


FIGURE B-10. DEFLECTION VS PRESSURE FOR DEVICES LM-10L & LM-11R

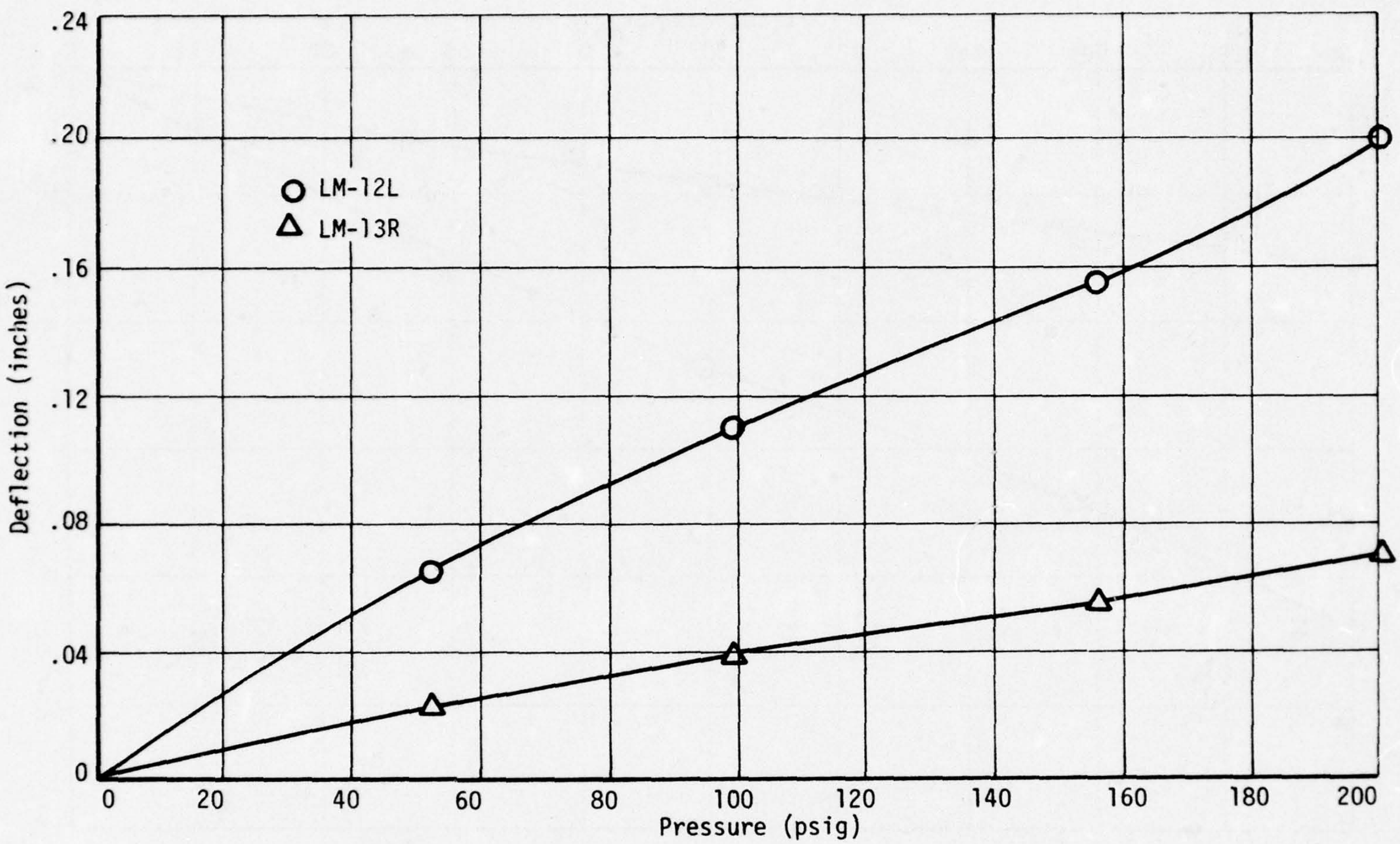


FIGURE B-11. DEFLECTION VS PRESSURE FOR DEVICES LM-12L & LM-13R

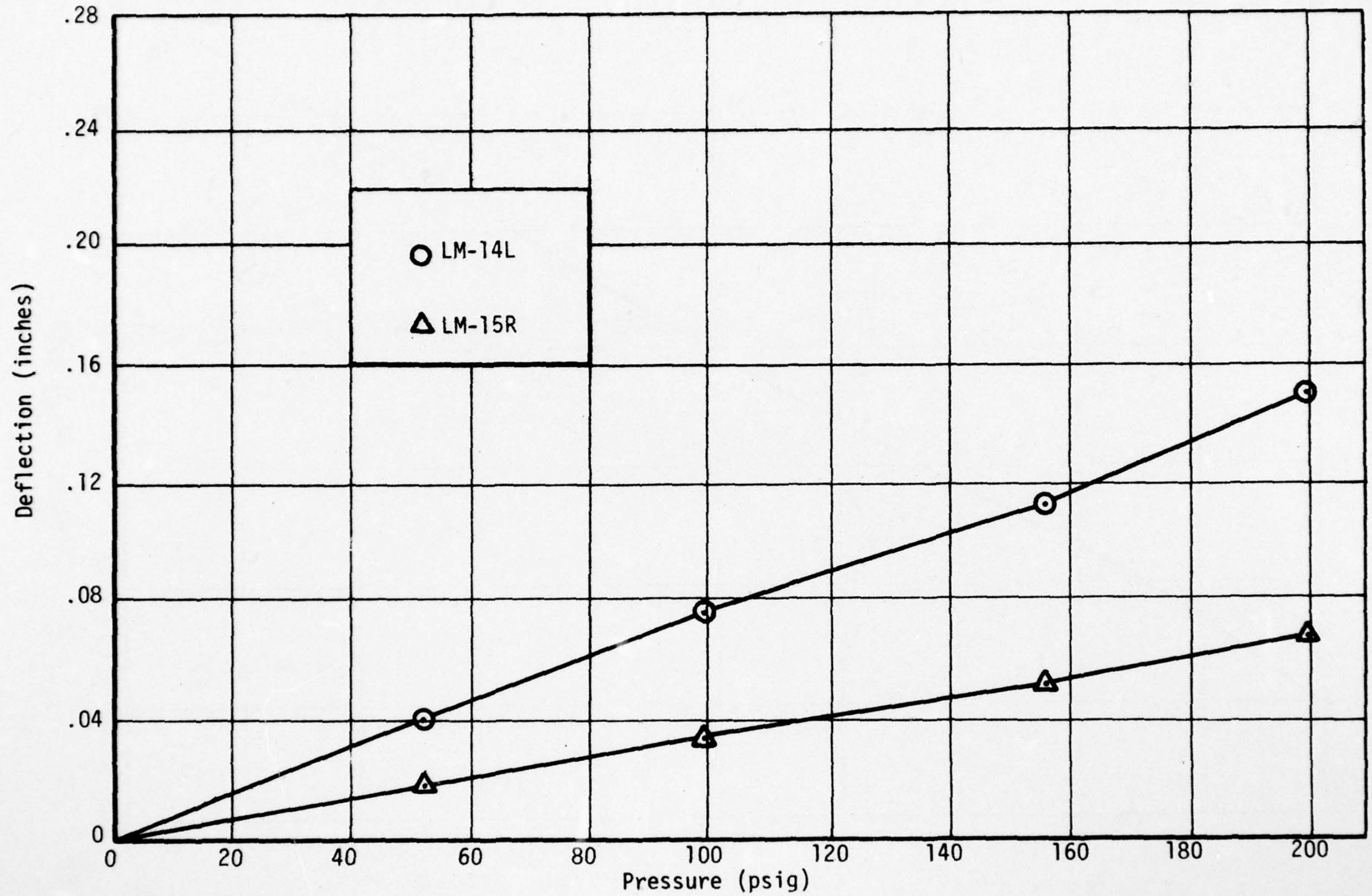


FIGURE B-12. DEFLECTION VS PRESSURE FOR DEVICES LM-14L & LM-15R

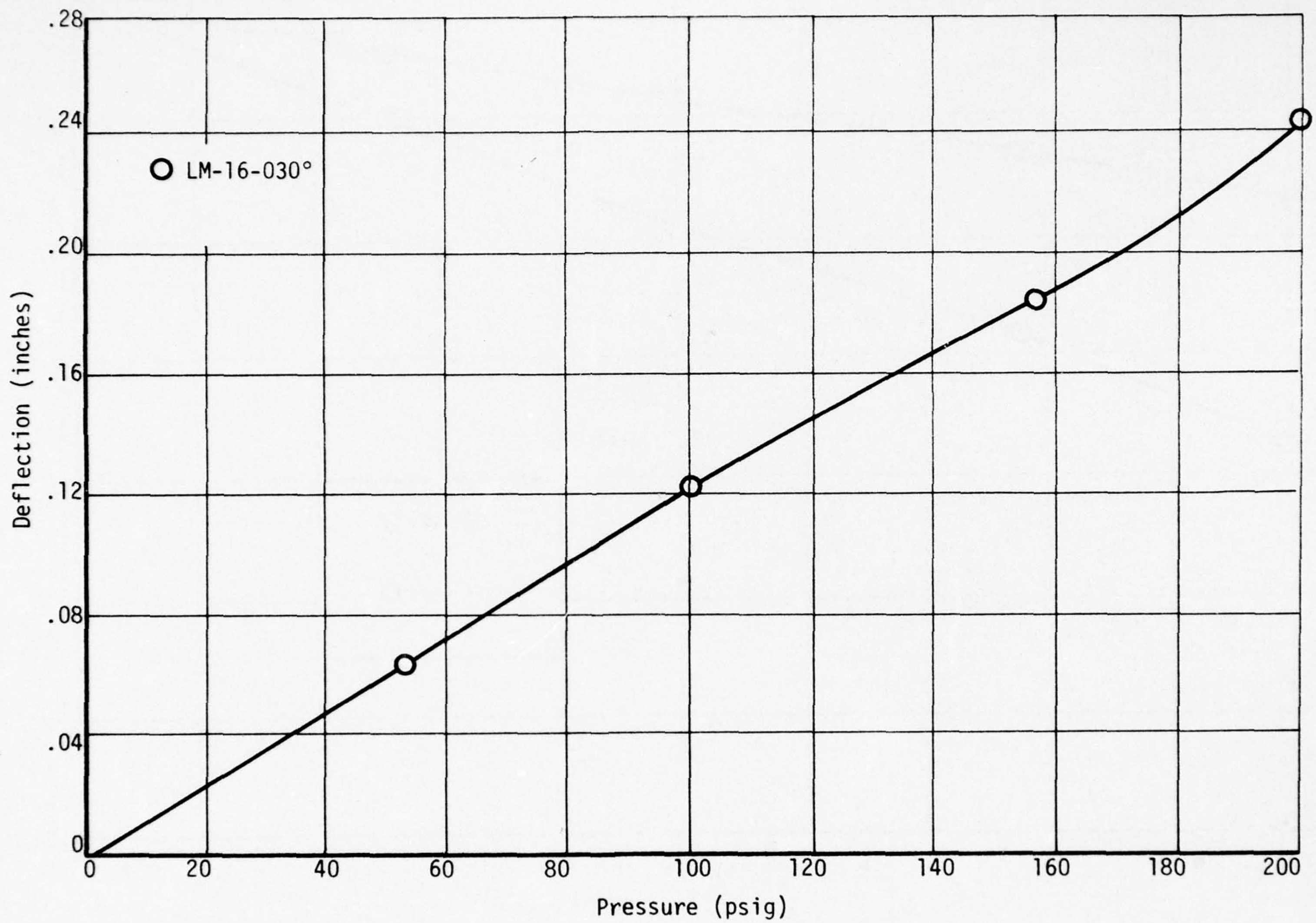


FIGURE B-13. DEFLECTION VS PRESSURE FOR DEVICE LM-16

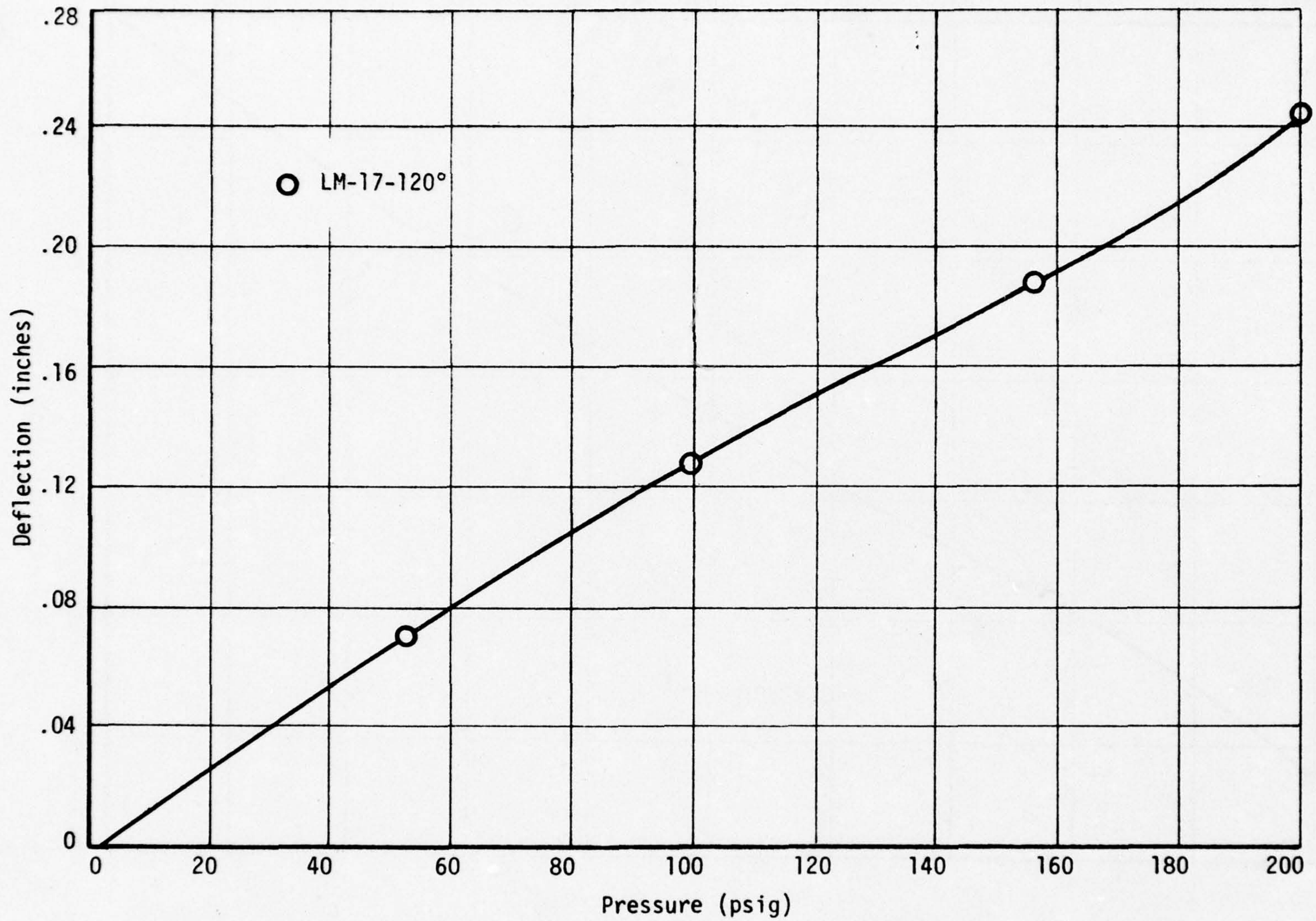


FIGURE B-14. DEFLECTION VS PRESSURE FOR DEVICE LM-17

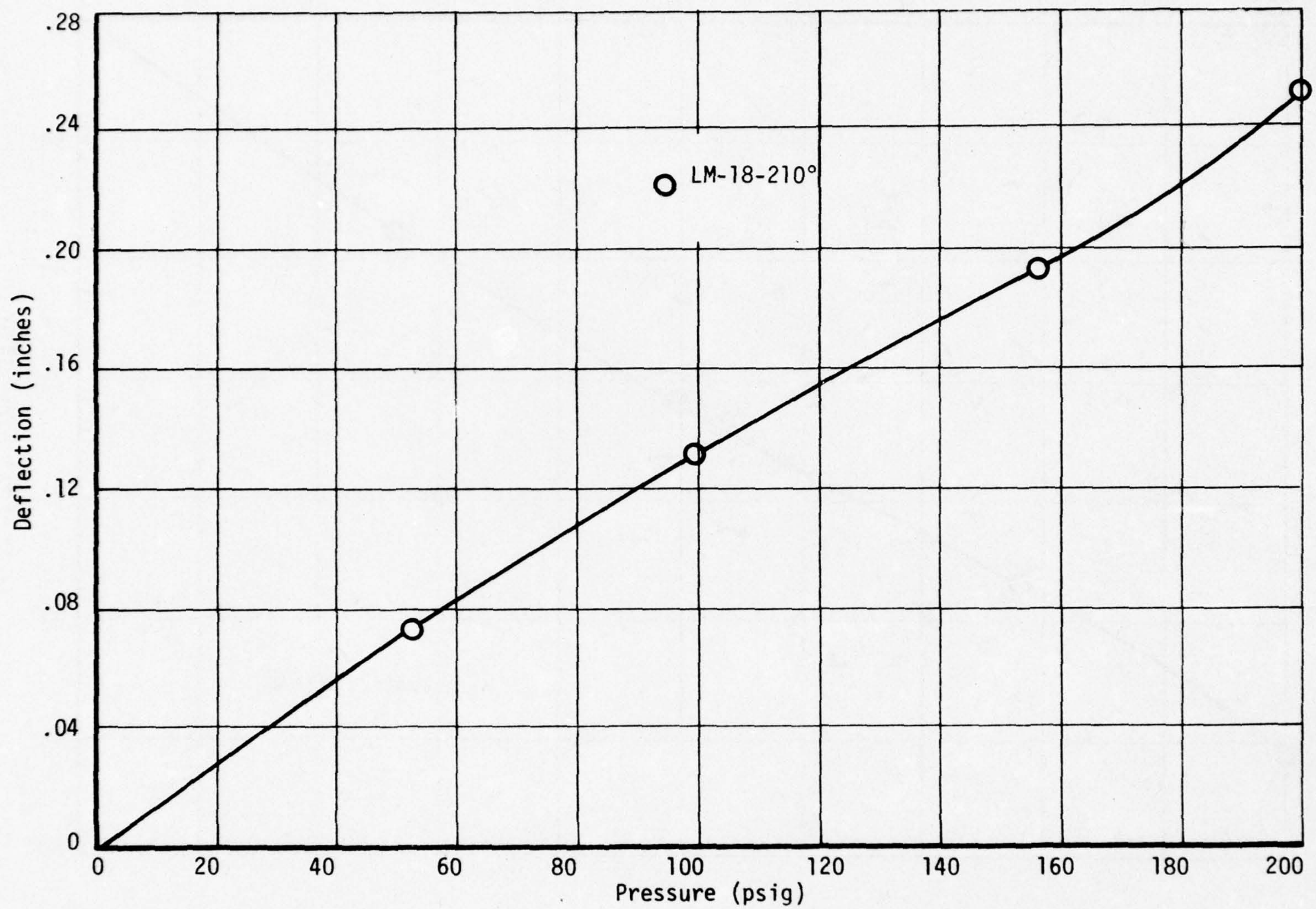


FIGURE B-15. DEFLECTION VS PRESSURE FOR DEVICE LM-18

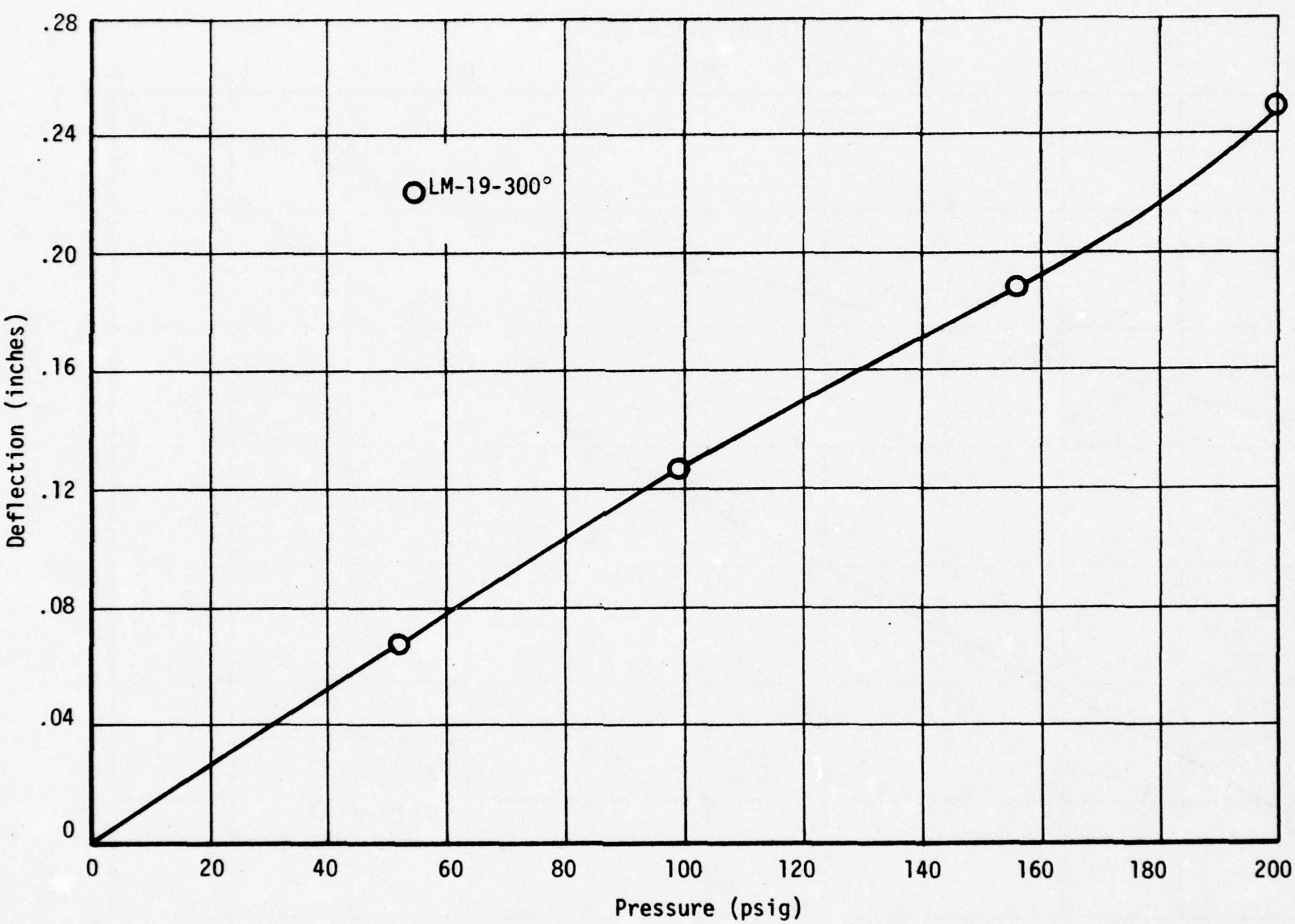


FIGURE B-16. DEFLECTION VS PRESSURE FOR DEVICE LM-19

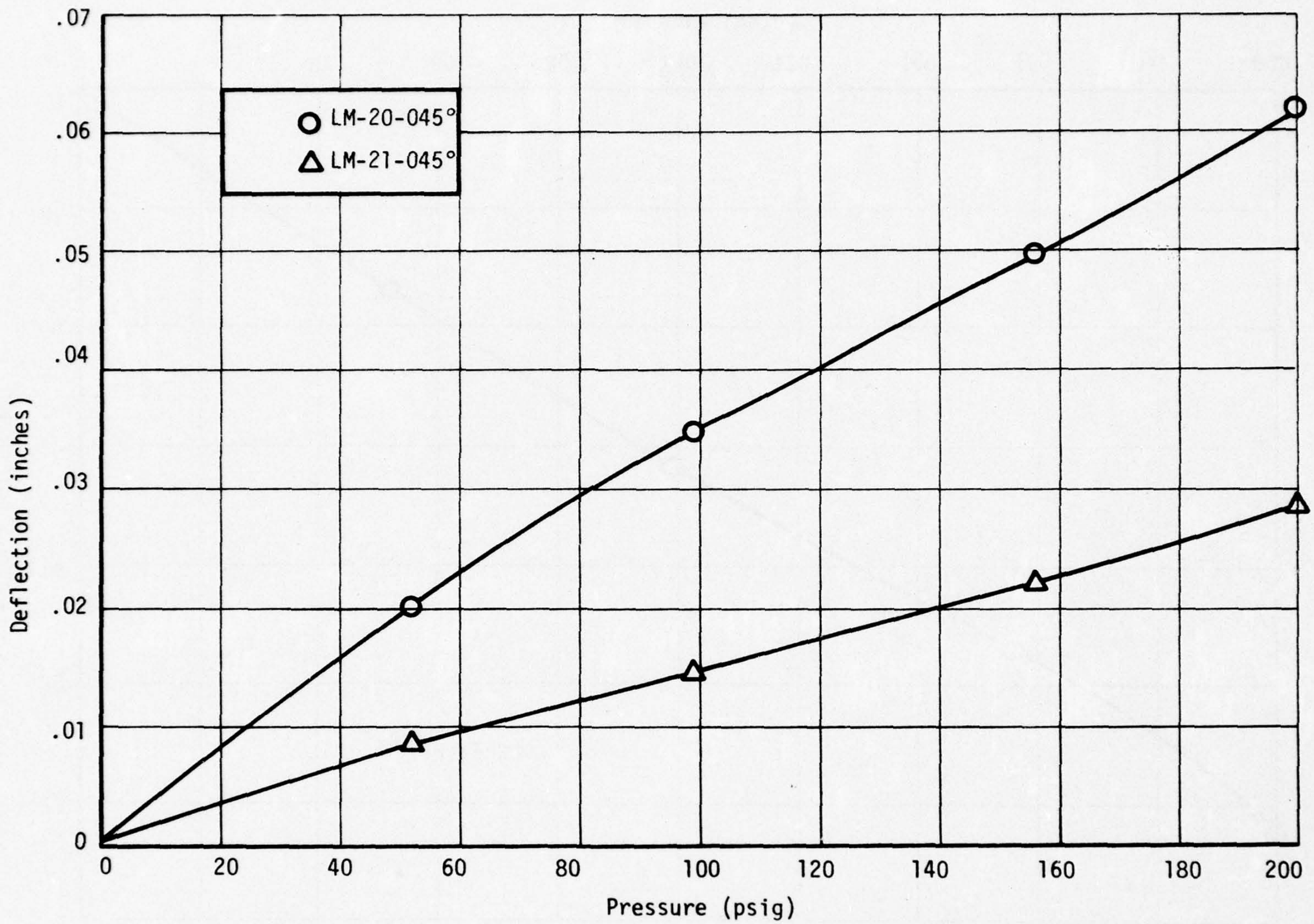


FIGURE B-17. DEFLECTION VS PRESSURE FOR DEVICES LM-20 & LM-21

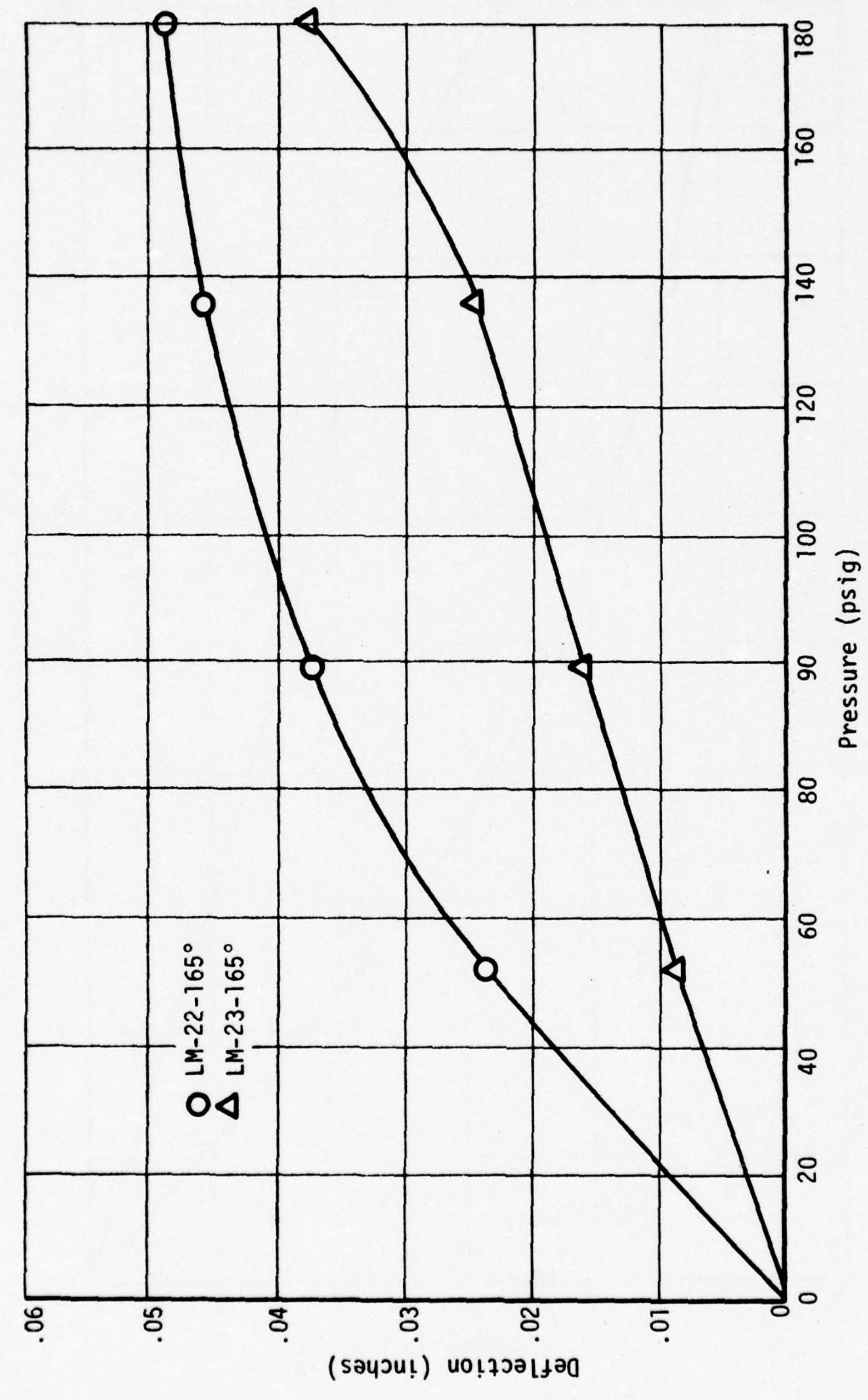


FIGURE B-18. DEFLECTION VS PRESSURE FOR DEVICES LM-22 & LM-23

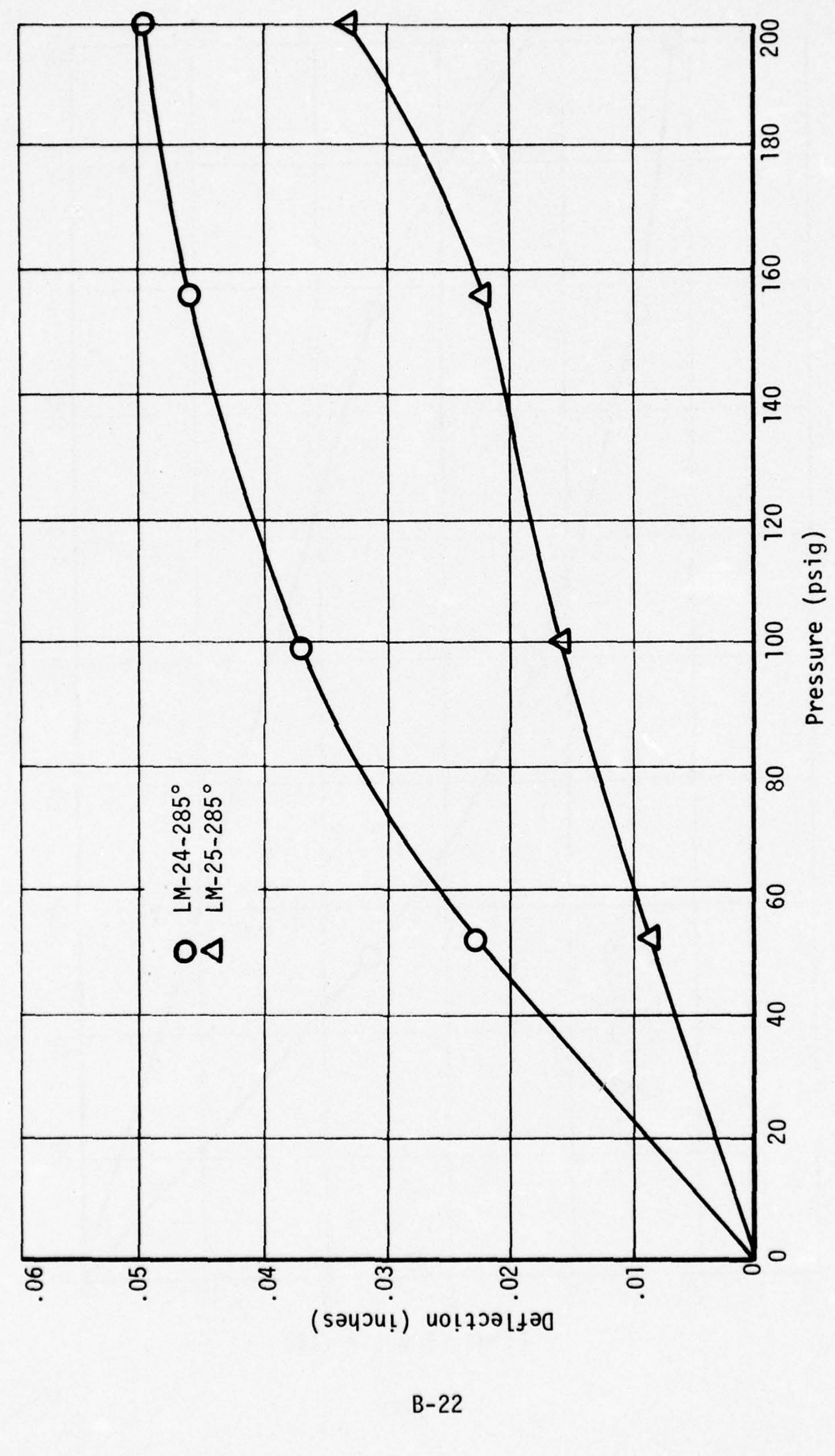


FIGURE B-19. DEFLECTION VS PRESSURE FOR DEVICES LM-29 & LM-25

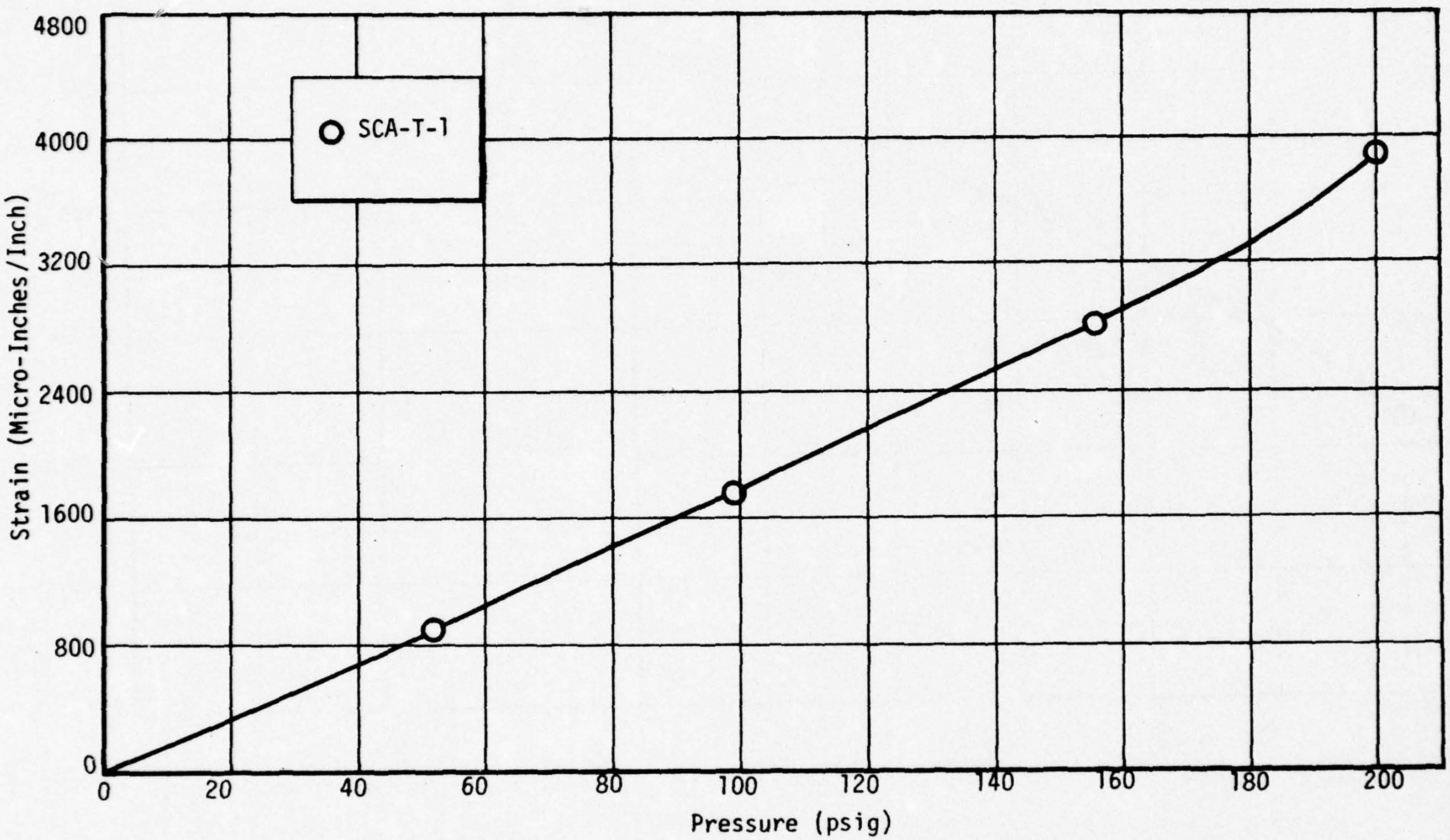


FIGURE B-20. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-1

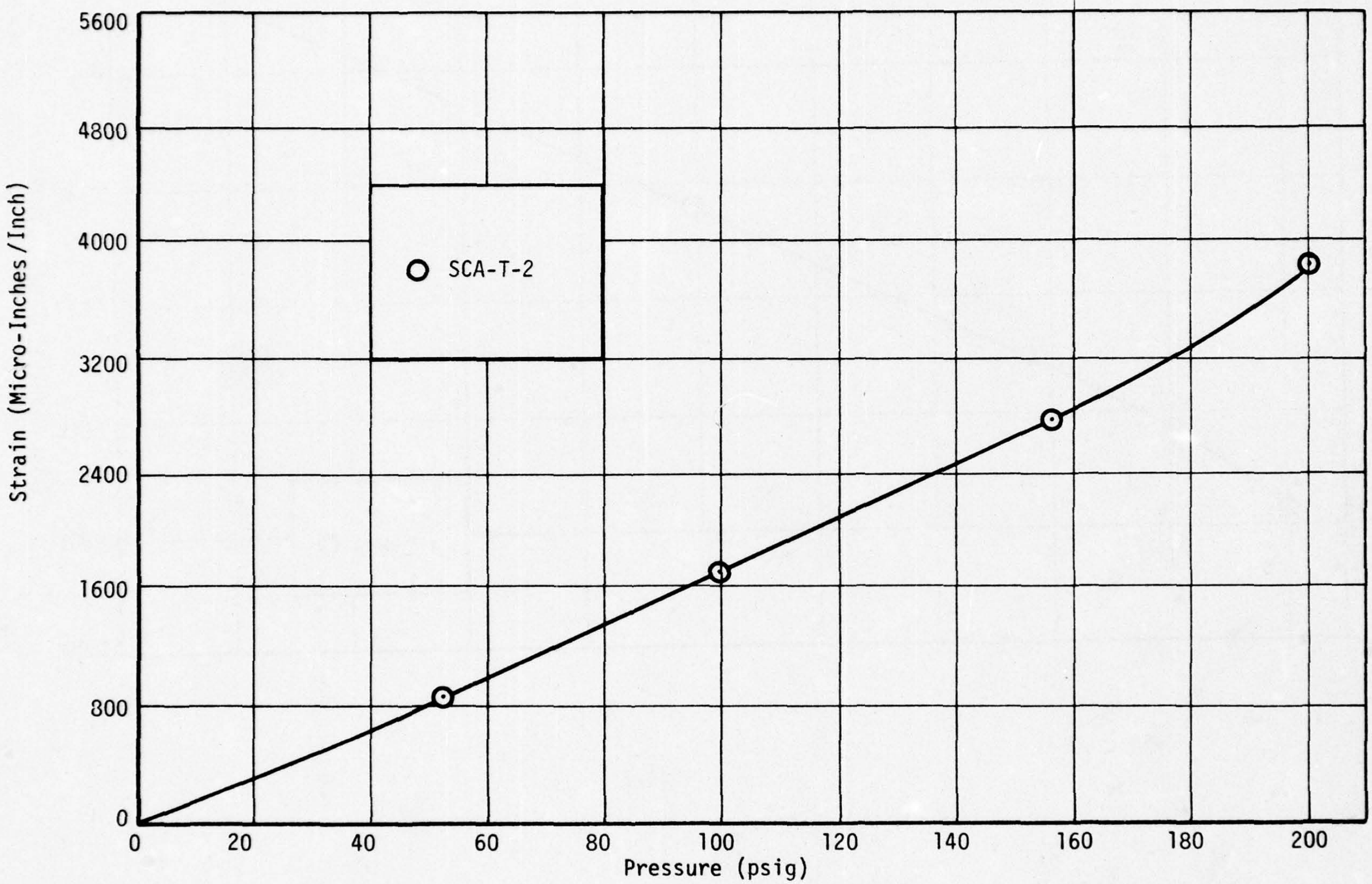


FIGURE B-21. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-2

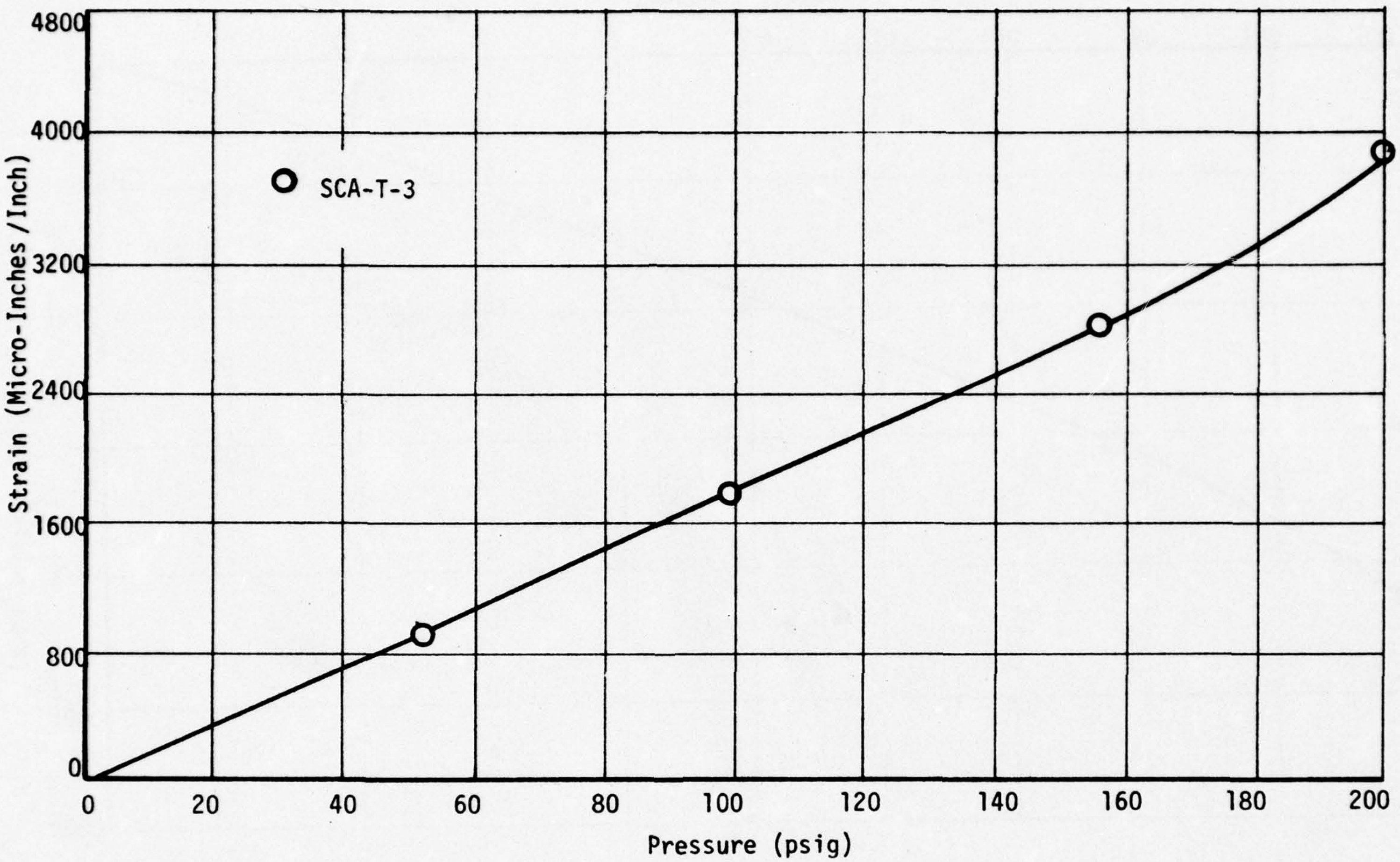


FIGURE B-22. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-3

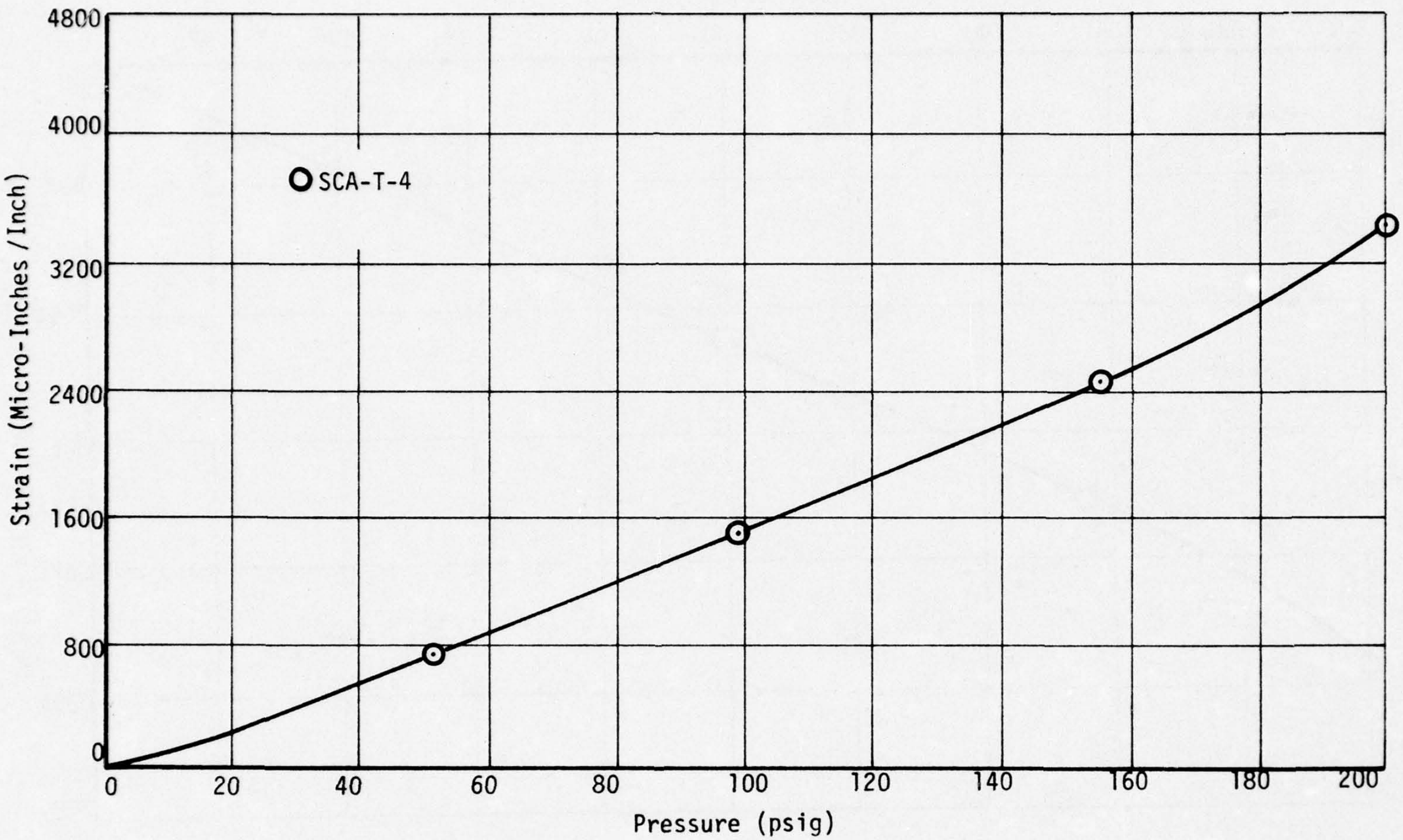


FIGURE B-23. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-4

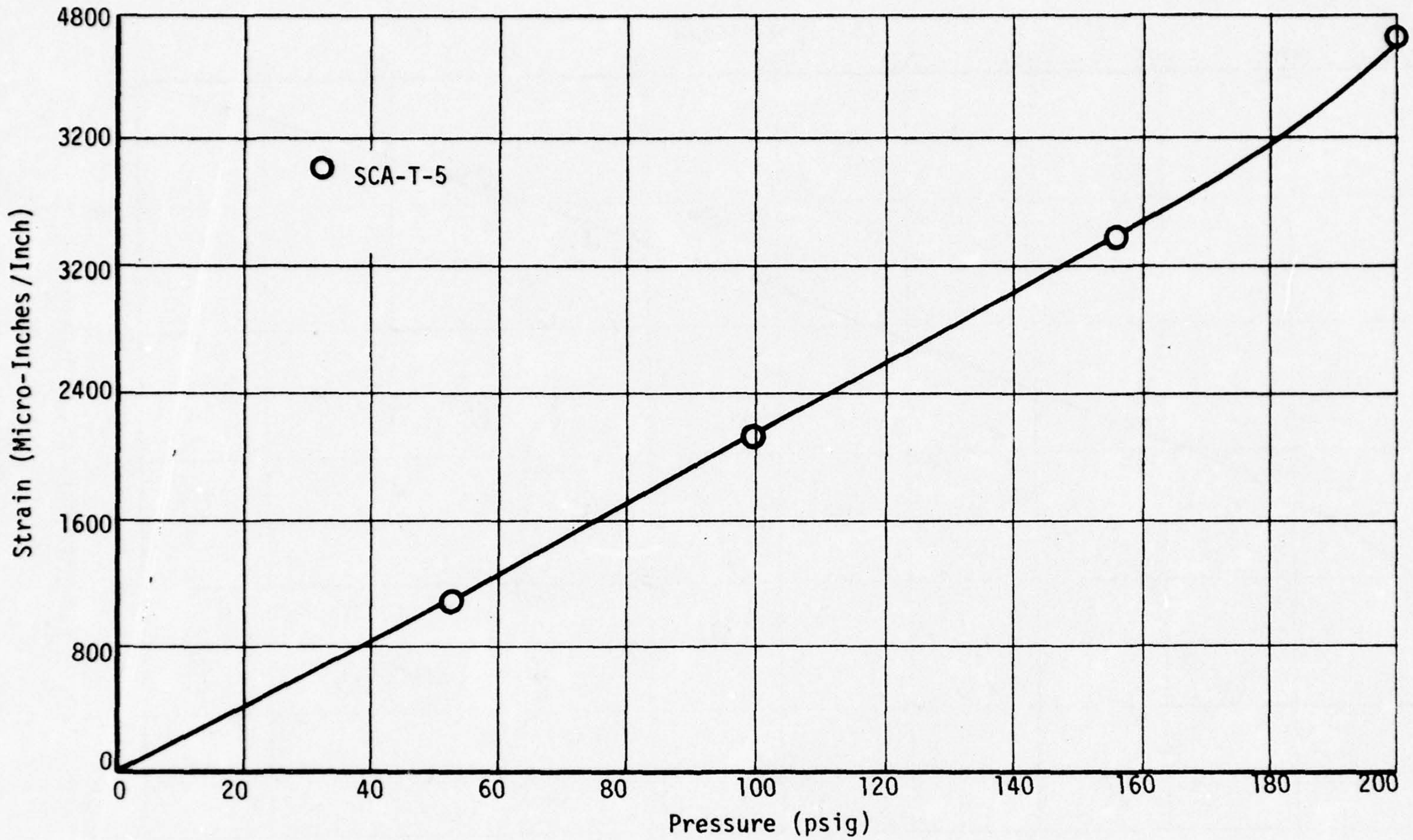


FIGURE B-24. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-5

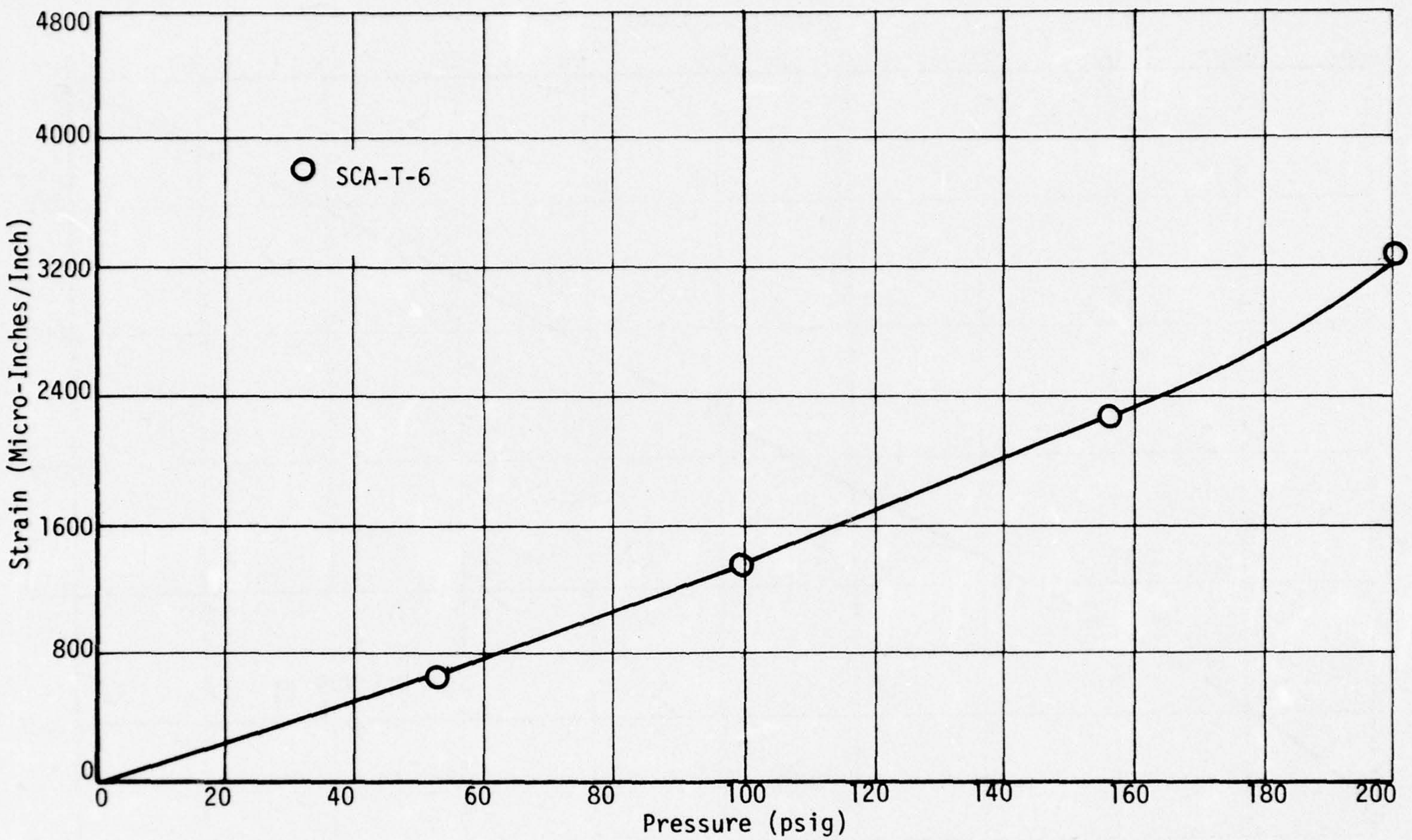


FIGURE B-25. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-6

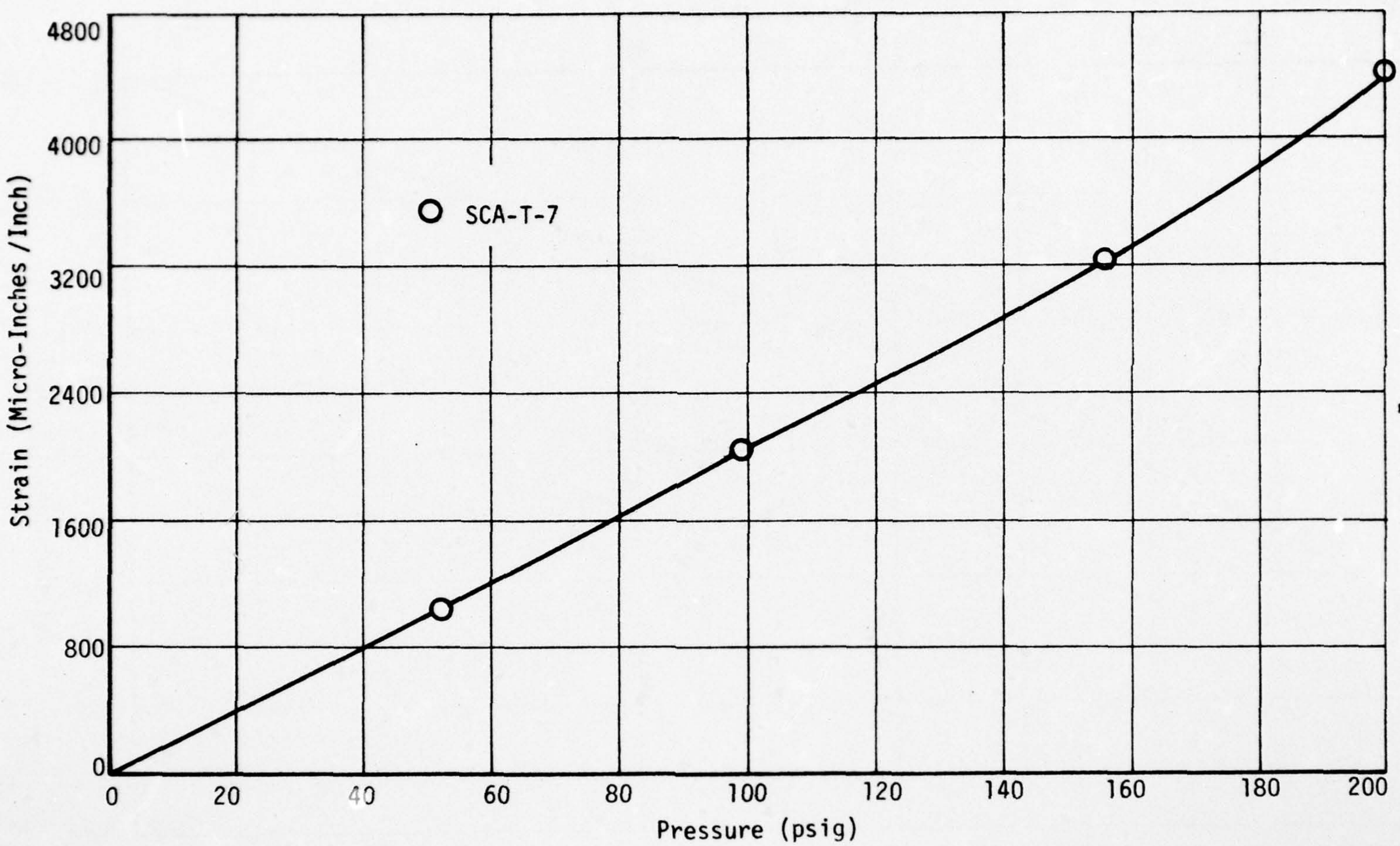


FIGURE B-26. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-7

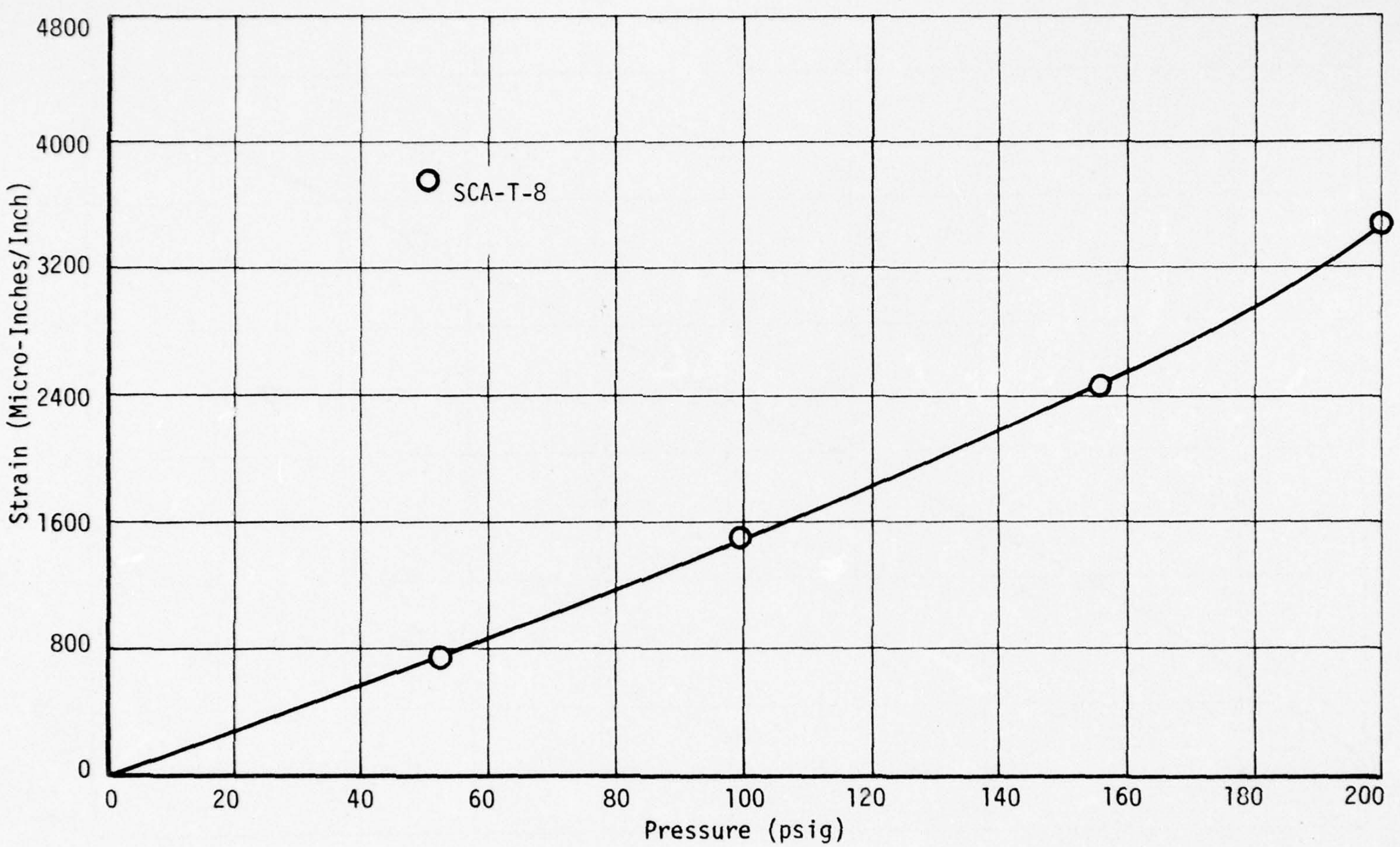


FIGURE B-27. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-8

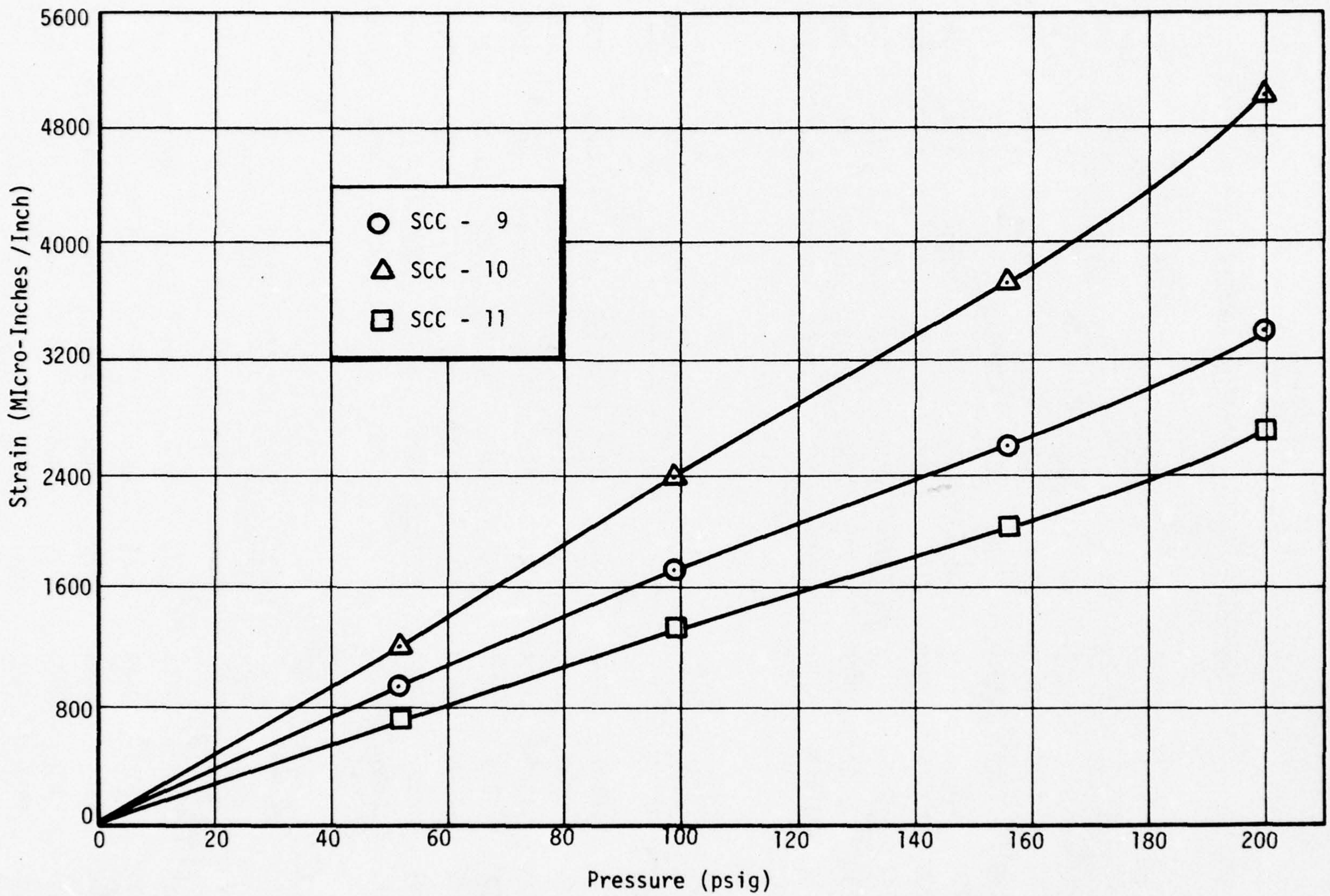


FIGURE B-28. STRAIN VS PRESSURE FOR CIRCUMFERENTIAL GAGE NOS. SCC-9, SCC-10, & SCC-11

TABLE B-1

HYDROTEST RESPONSE DATA FOR CHAMBER S/N 30113

Deflections - Inches

PC (psig)	LM-1L	LM-2R	LM-3L	LM-4R	LM-5L	LM-6R	LM-7L-120°	LM-8L-240°	LM-9L-0°
52	.1310	.0098	.1341	.002	.1358	.0058	.1500	.1450	.1500
99	.2310	.0168	.2295	.020	.2286	.0105	.2625	.2452	.2614
156	.3238	.0218	.3143	.032	.3182	.0152	.3775	.3428	.3605
200	.3976	.0240	.3727	.040	.3886	.0181	.4714	.4350	.4579
142	.3905	.0182	.2952	.036	.3068	.0138	.3600	.3214	.3405
101	.2357	.0138	.2273	.034	.2405	.0107	.2725	.2381	.2568
52	.1310	.0070	.1318	.028	.1500	.0058	.1591	.1300	.1350

PC (psig)	LM-10L	LM-11R	LM-12L	LM-13R	LM-14L	LM-15R	LM-16-30°	LM-17-120°	LM-18-210°
52	.0525	.0235	.0443	.0220	.0405	.0190	.0643	.0714	.0738
99	.0950	.0373	.0895	.0381	.0762	.0345	.1238	.1286	.1310
156	.1364	.0504	.1348	.0545	.1125	.0520	.1857	.1886	.1928
200	.1773	.0622	.1800	.0700	.1500	.0685	.2452	.2452	.2524
142	.1318	.0477	.1276	.0515	.1100	.0475	.1810	.1818	.1881
101	.0950	.0359	.0895	.0381	.0810	.0330	.1310	.1357	.1405
52	.0500	.0222	.0419	.0205	.0428	.0170	.0714	.0786	.0833

PC (psig)	LM-19-300°	LM-20-45°	LM-21-45°	LM-22-165°	LM-23-165°	LM-24-285°	LM-25-285°
52	.0667	.0198	.0084	.0236	.0089	.0228	.0087
99	.1262	.0348	.0145	.0370	.0162	.0370	.0160
156	.1881	.0495	.0220	.0457	.0245	.0460	.0223
200	.2500	.0620	.0285	.0486	.0376	.0497	.0332
142	.1857	.0463	.0205	.0443	.0273	.0406	.0227
101	.1357	.0340	.0150	.0368	.0200	.0320	.0160
52	.0762	.0182	.0095	.0225	.0114	.0205	.0083

TABLE B-2

HYDROTEST RESPONSE DATA FOR CHAMBER S/N 30113

PC (psig)	Strain - Microinches/Inch SCAT-1	SCAT-2	SCAT-3	SCAT-4	SCAT-5	SCAT-6	SCAT-7	SCAT-8
52	887	835	910	719	1092	647	1039	736
99	1749	1693	1778	1489	2135	1351	2023	1497
156	2810	2751	2812	2448	3383	2265	3211	2462
200	3888	3809	3879	3482	4631	3276	4399	3476
142	2736	2679	2746	2316	3276	2192	3085	2397
101	1923	1860	1943	1555	2299	1472	2149	1652
52	987	938	1001	719	1174	696	1078	834

PC (psig)	SCC-9	SCC-10	SCC-11
52	953	1223	711
99	1748	2397	1332
156	2595	3742	2030
200	3389	5039	2715
142	2489	3522	1952
101	1814	2495	1409
52	1006	1296	763

TABLE B-3

SUMMARY RESPONSE DATA FOR CHAMBER S/N 30113

Hoop Strains at Barrel Section (Micro inches/inch)		Pressure, psig 0	52	99	156	200
Forward Equator		0	953	1748	2595	3389
Mid Barrel		0	1223	2397	3742	5039
Aft Equator		0	711	1332	2030	2715
Fwd Dome Deflections (inches)						
7.1 Radius	Longitudinal	0	.1310	.2310	.3238	.3976
	Radial	0	.0098	.0168	.0218	.0240
10.5 Radius	Longitudinal	0	.1341	.2295	.3143	.3727
	Radial	0	.0020	.0200	.0320	.0400
14.3 Radius	Longitudinal	0	.1358	.2286	.3182	.3886
	Radial	0	.0058	.0105	.0152	.0181
Aft Dome Deflections (inches)						
14.3 Radius	Longitudinal	0	.0525	.0950	.1364	.1773
	Radial	0	.0235	.0373	.0504	.0622
17.0 Radius	Longitudinal	0	.0443	.0895	.1348	.1800
	Radial	0	.0220	.0381	.0545	.0700
19.9 Radius	Longitudinal	0	.0405	.0762	.1125	.1500
	Radial	0	.0190	.0345	.0520	.0685

APPENDIX C

HYDROTEST DATA FOR CHAMBER S/N 30114

HYDROTEST DATA FOR CHAMBER S/N 30113

Tabulated data and plots of case deflection and strain versus internal pressure are given for each measuring device. Tables C-1 and C-2 list the data of the deflection devices and strain gages, while Table C-3 summarizes the more pertinent data; i.e., of the hoop strains in the barrel, and the forward and aft dome deflections. Graphic illustrations of the hoop strains in the cylinder section and the aft and forward dome deflections of 200 psig are shown in Figures C-1, C-2, and C-3. Figures C-4 to C-9 show the curves for the forward head deflection versus pressure, while Figures C-10 to C-16 show the aft head deflections versus pressure. Figures C-17 to C-19 show the longitudinal strain in the barrel section. Figures C-20 to C-27 show the strains in the aft head. Figure C-28 presents the circumferential growth of the case with chamber pressurization.

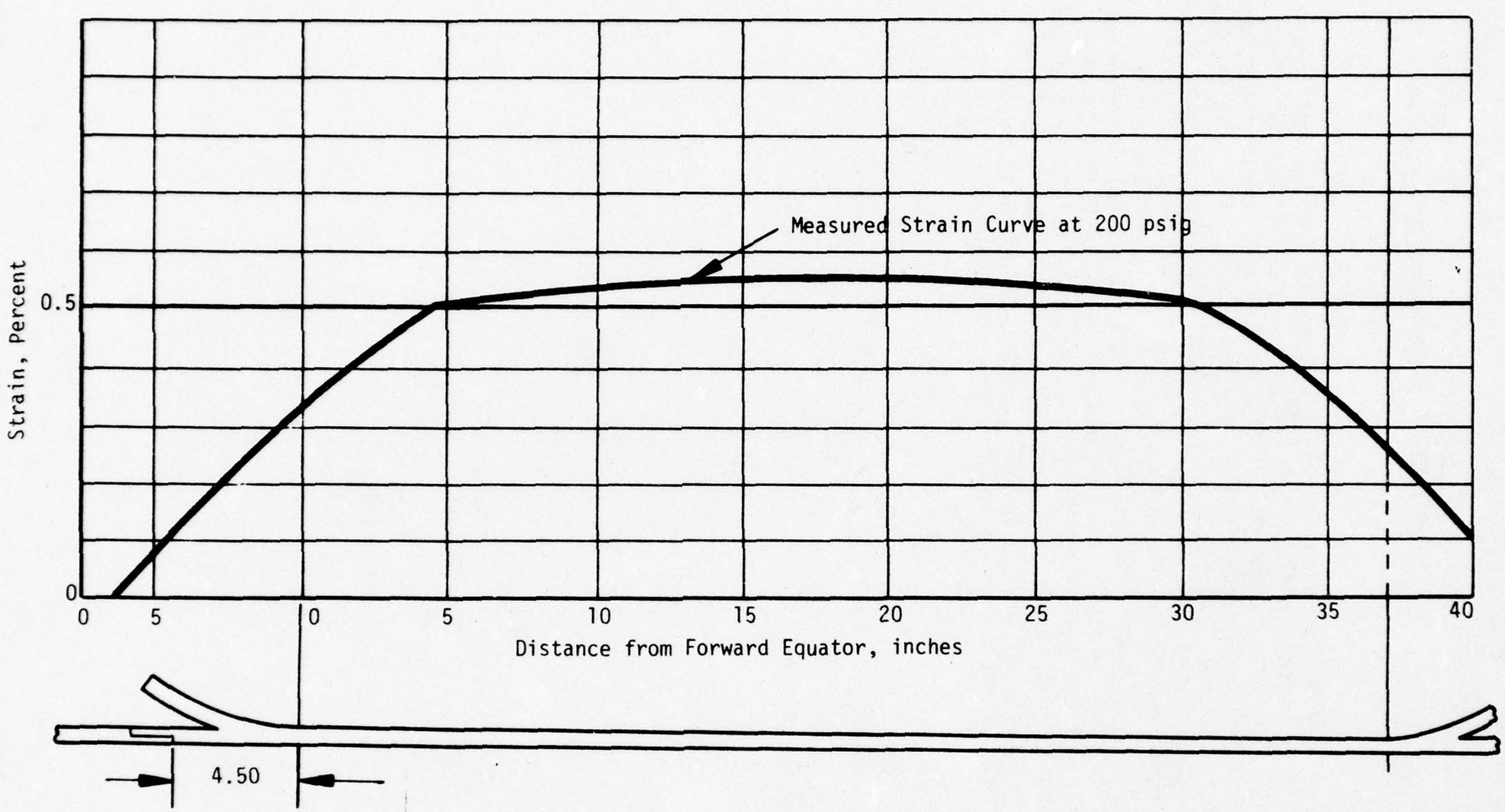


FIGURE C-1. HOOP STRAIN IN CYLINDER SECTION AT 200 PSIG

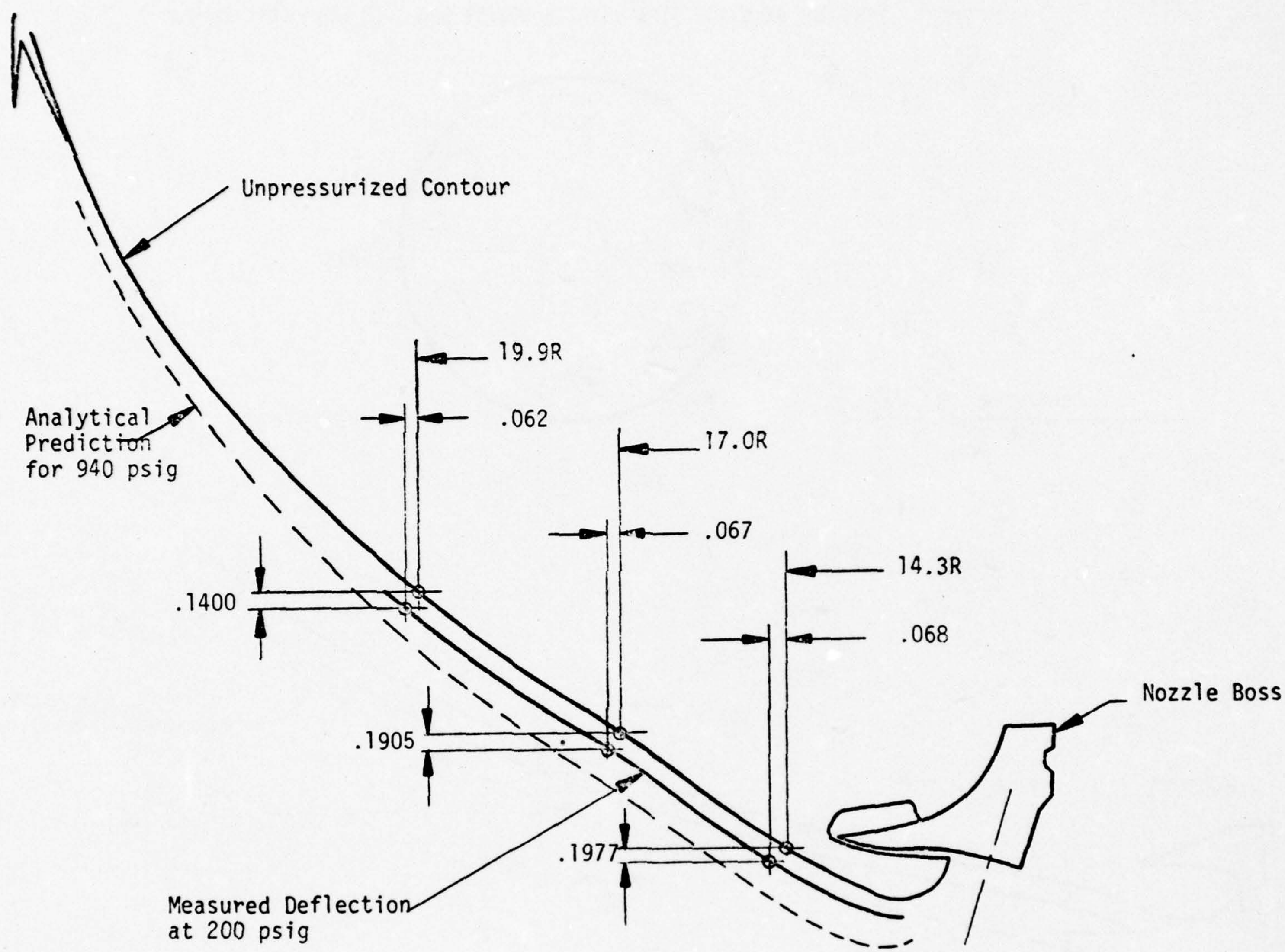


FIGURE C-2. AFT DOME DEFLECTION AT 200 PSIG (INCHES)

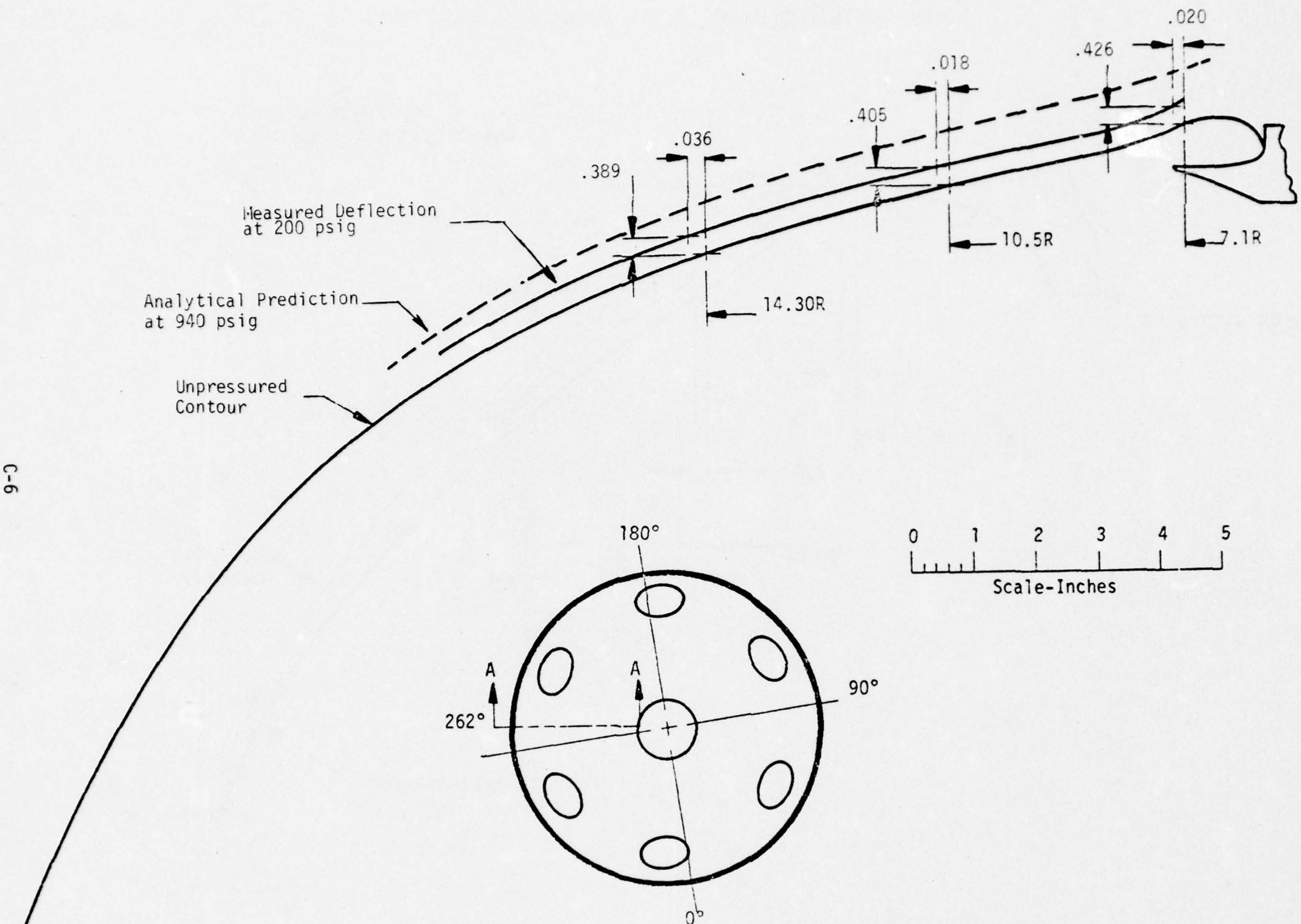


FIGURE C-3. FWD DOME DEFLECTION BETWEEN T.T. PORTS AT 200 PSIG (INCHES)

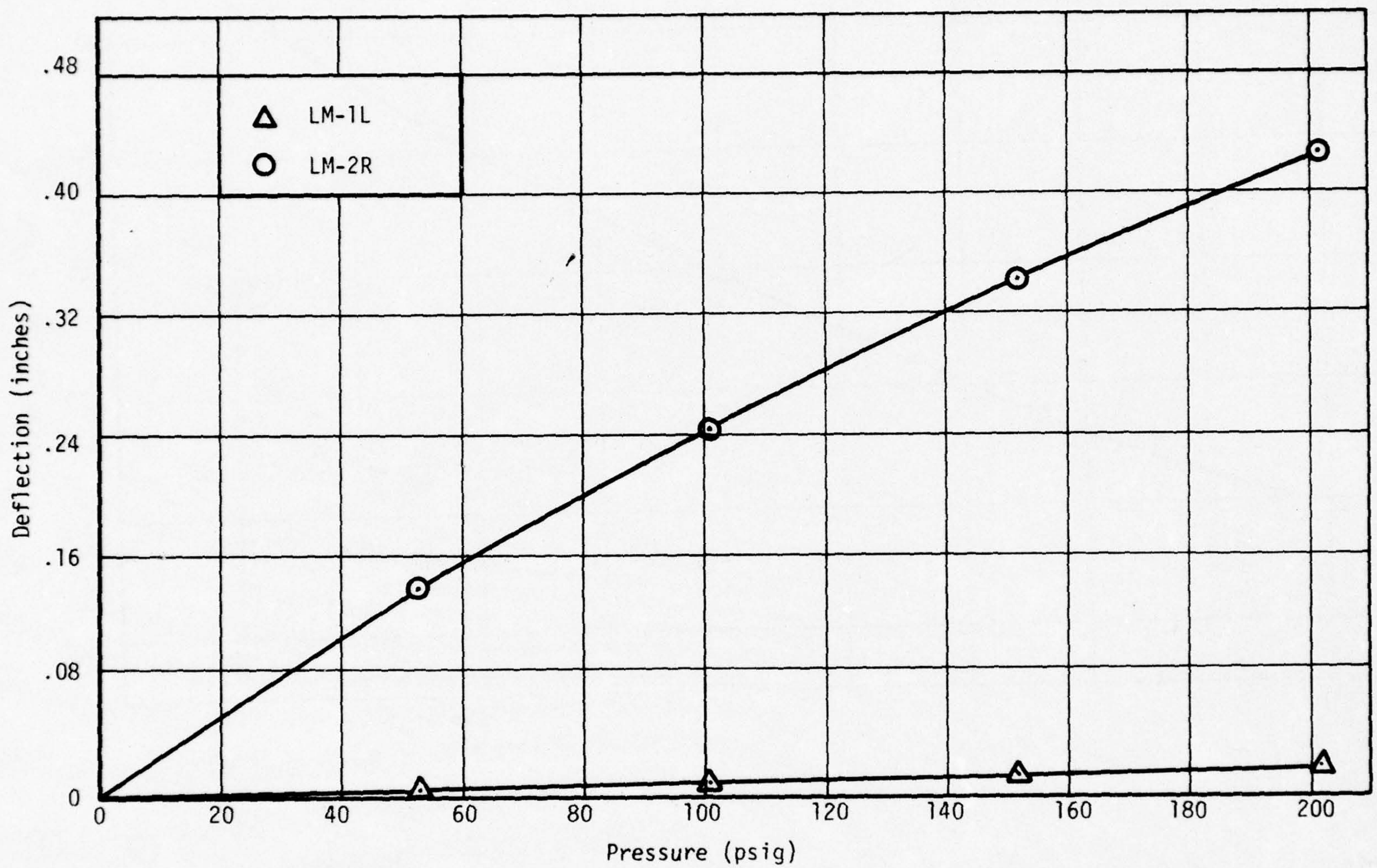


FIGURE C-4. DEFLECTION VS INTERNAL PRESSURE FOR DEFLECTION DEVICES LM-1L & LM-2R

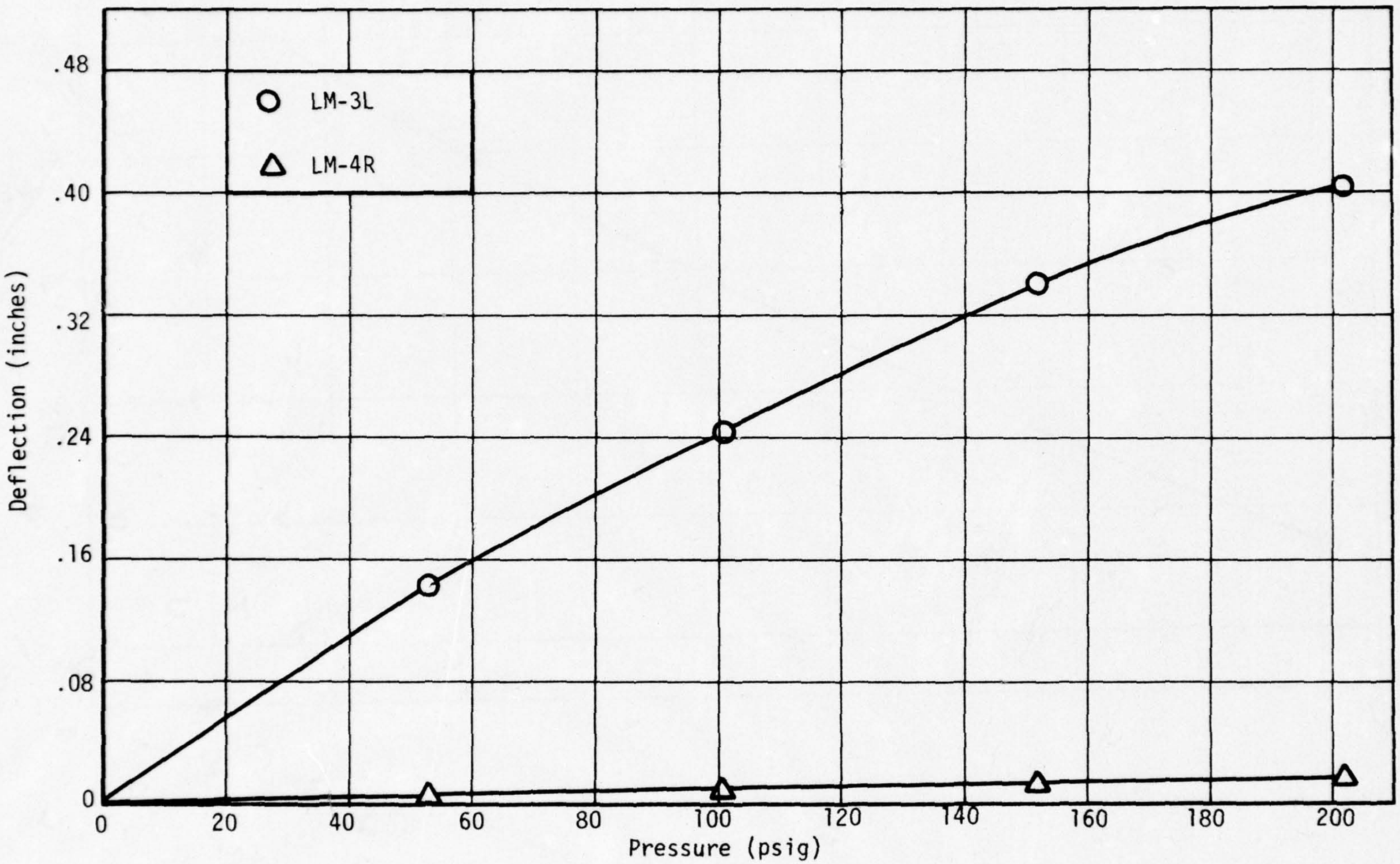


FIGURE C-5. DEFLECTION VS INTERNAL PRESSURE FOR DEFLECTION DEVICES LM-3L & LM-4R

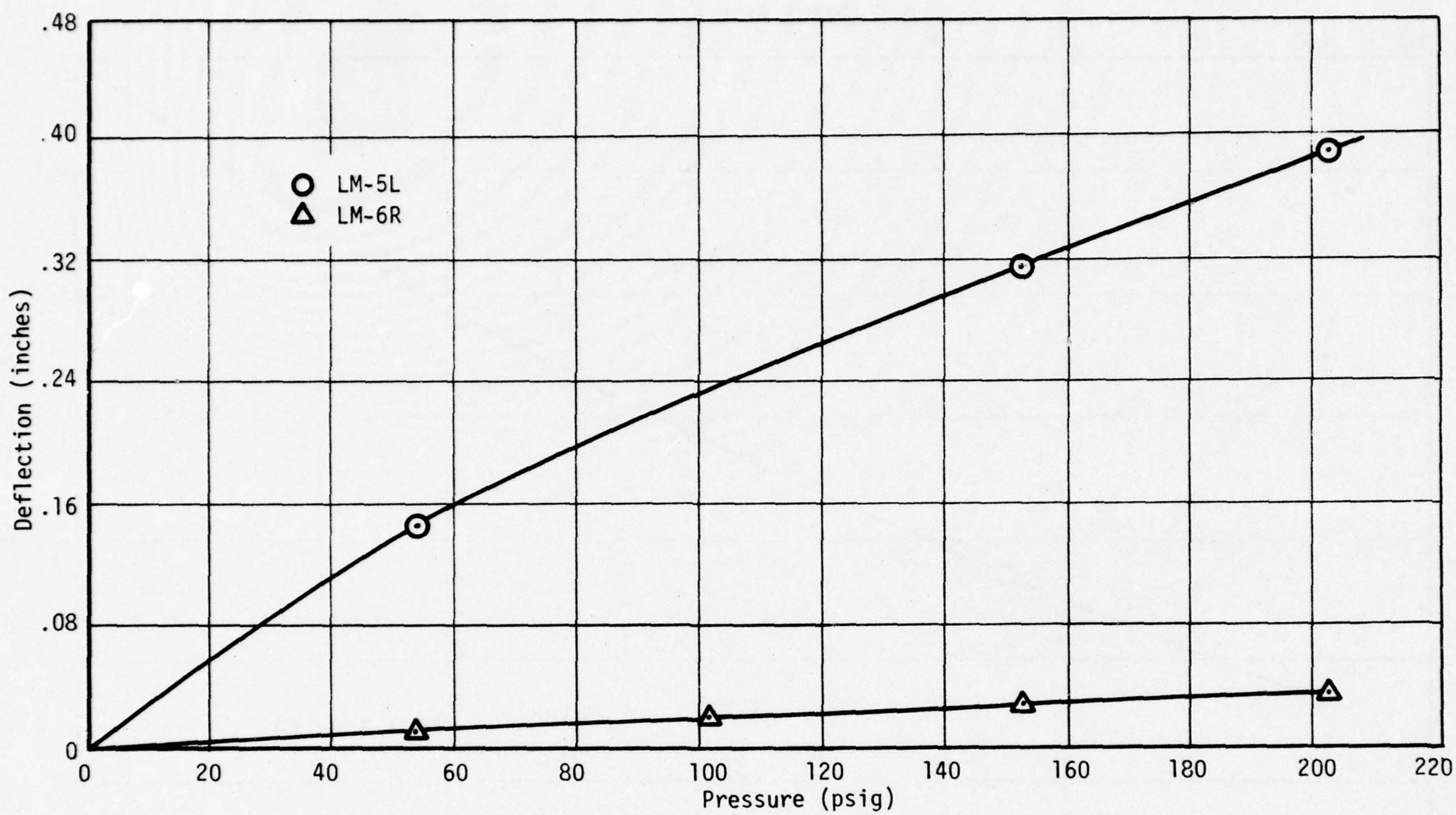


FIGURE C-6. DEFLECTION VS PRESSURE FOR DEVICES LM-5L & LM-6R

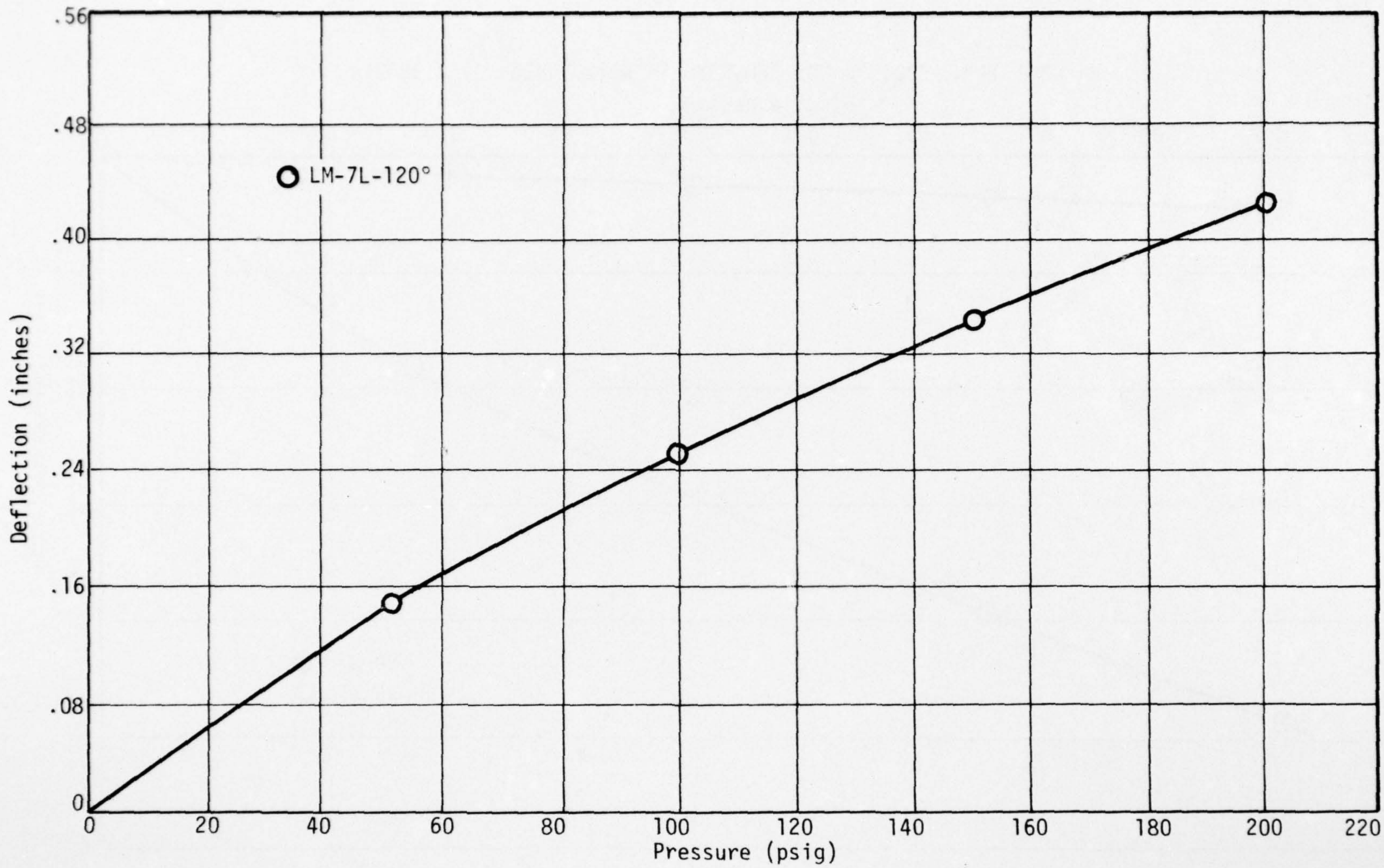


FIGURE C-7. DEFLECTION VS PRESSURE FOR DEVICE LM-7L

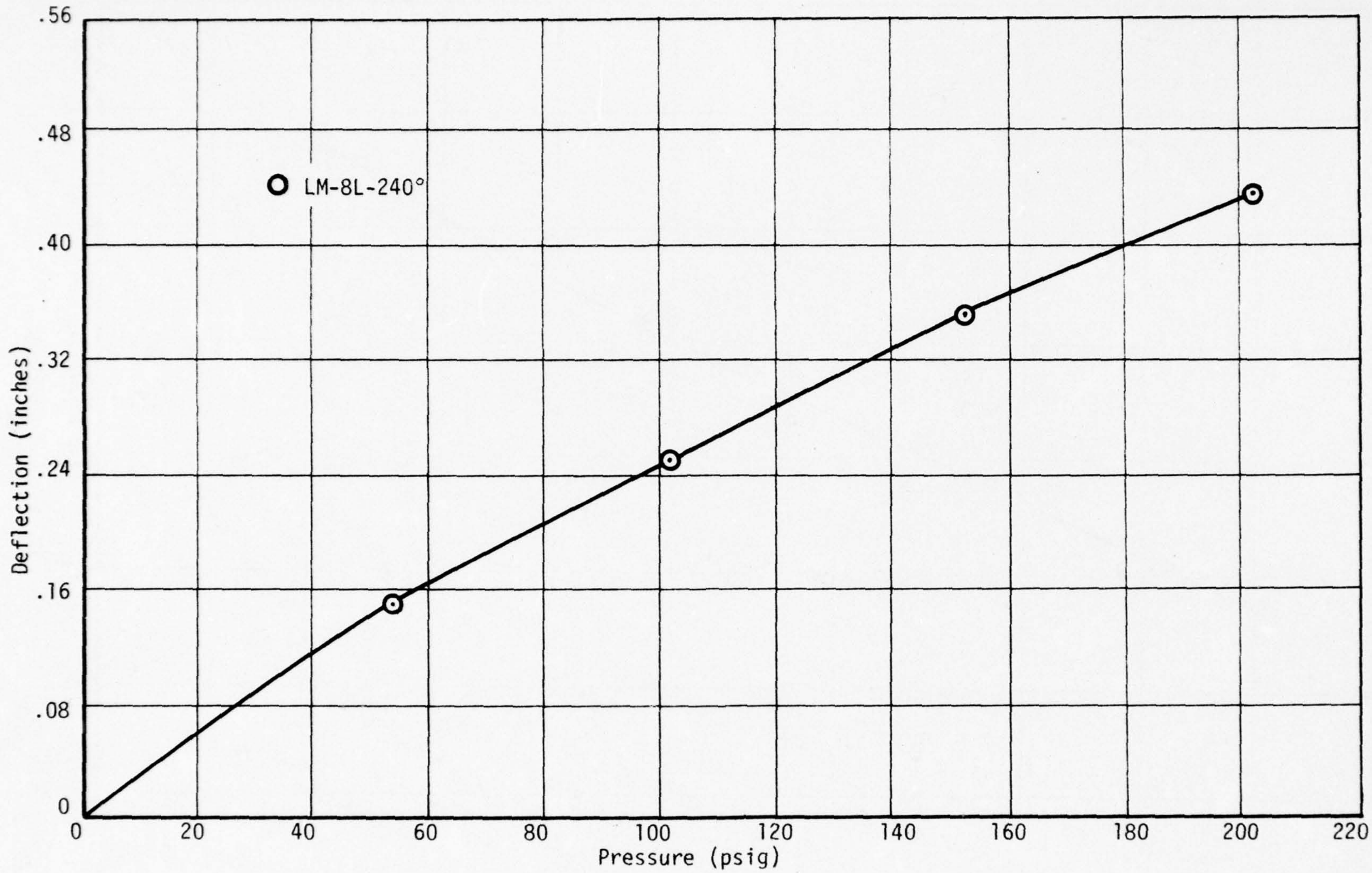


FIGURE C-8. DEFLECTION VS PRESSURE FOR DEVICE LM-8L

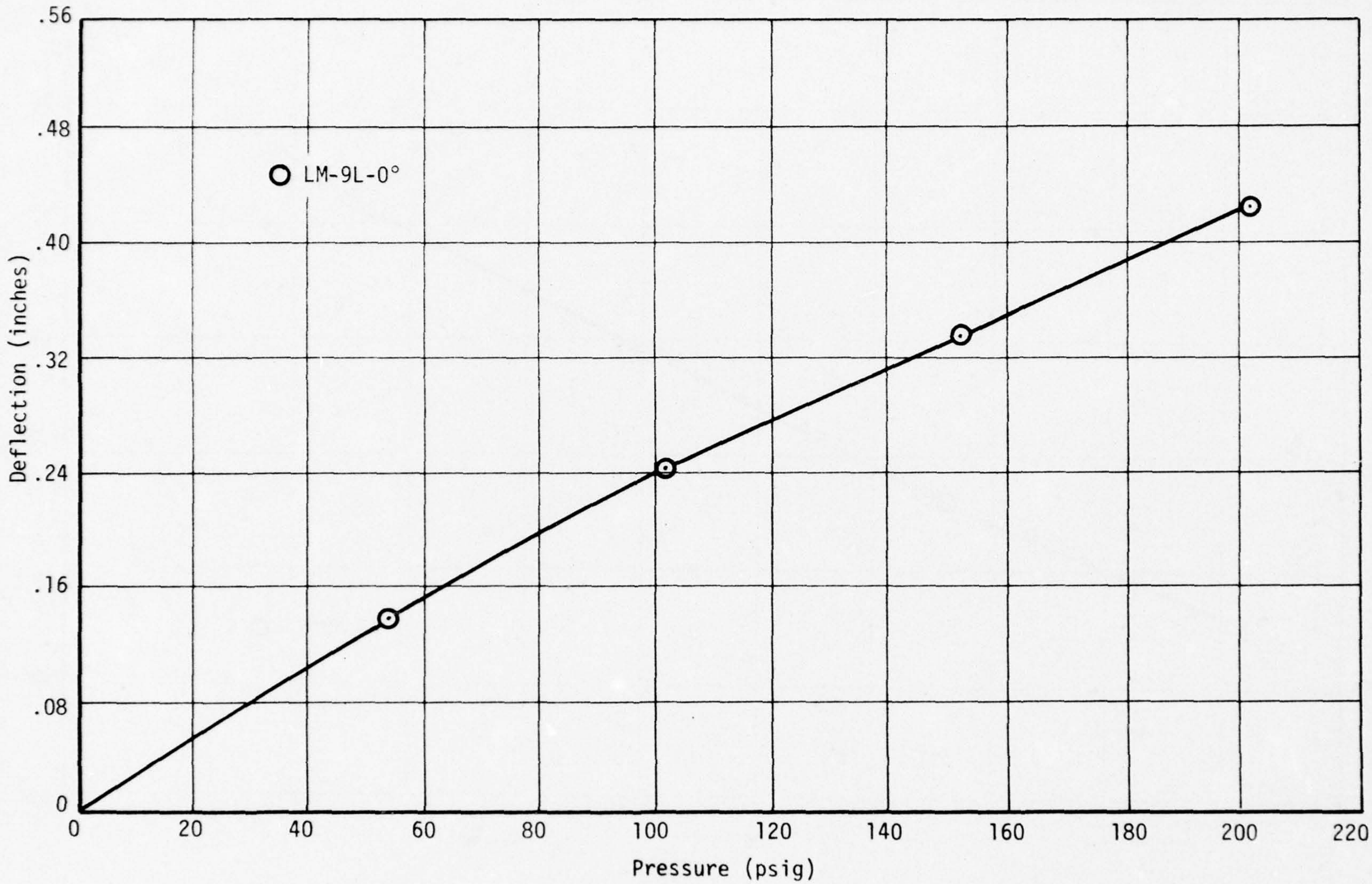


FIGURE C-9. DEFLECTION VS PRESSURE FOR DEVICES LM-9L

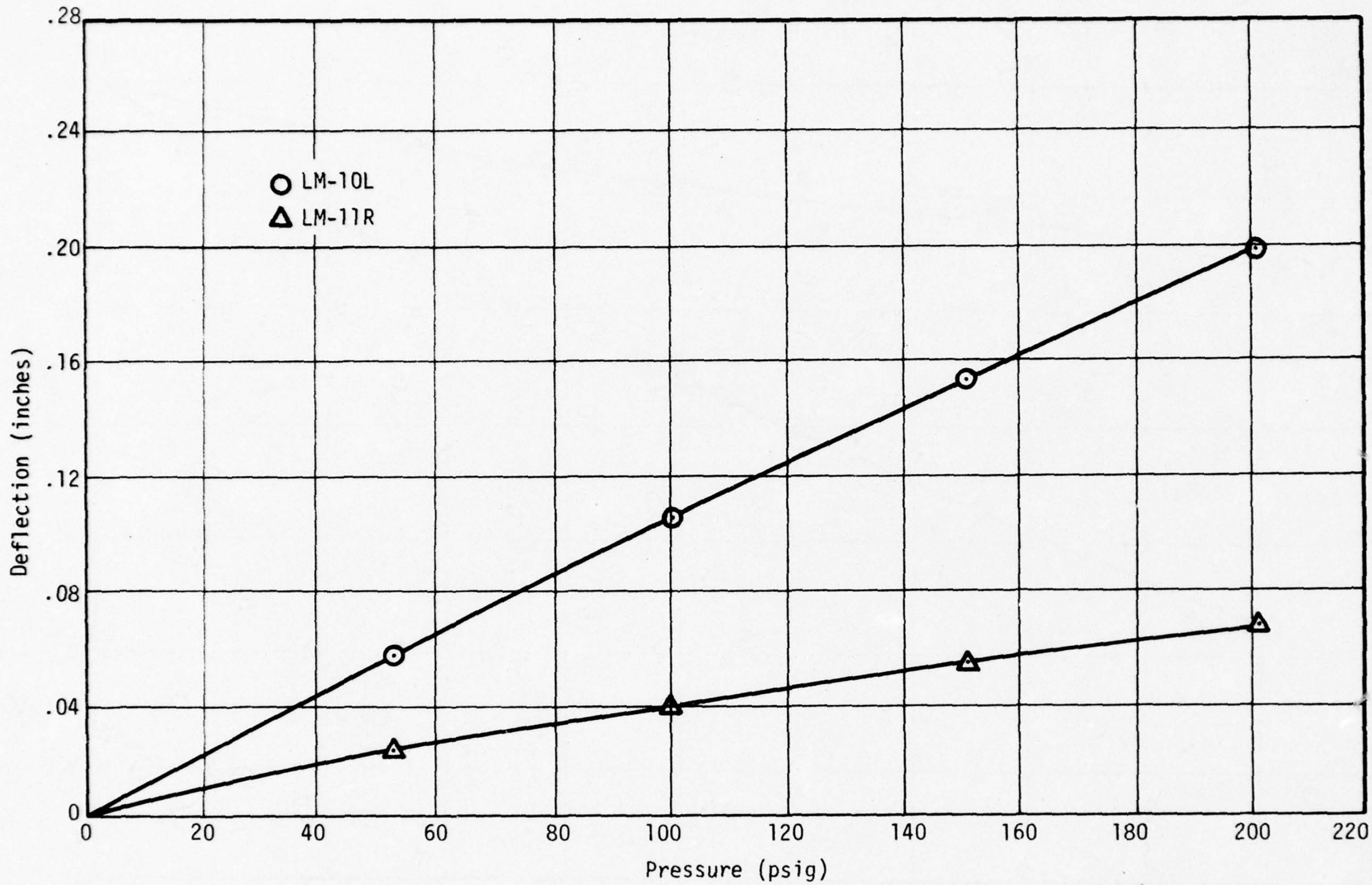


FIGURE C-10. DEFLECTION VS PRESSURE FOR DEVICES LM-10L AND LM-11R

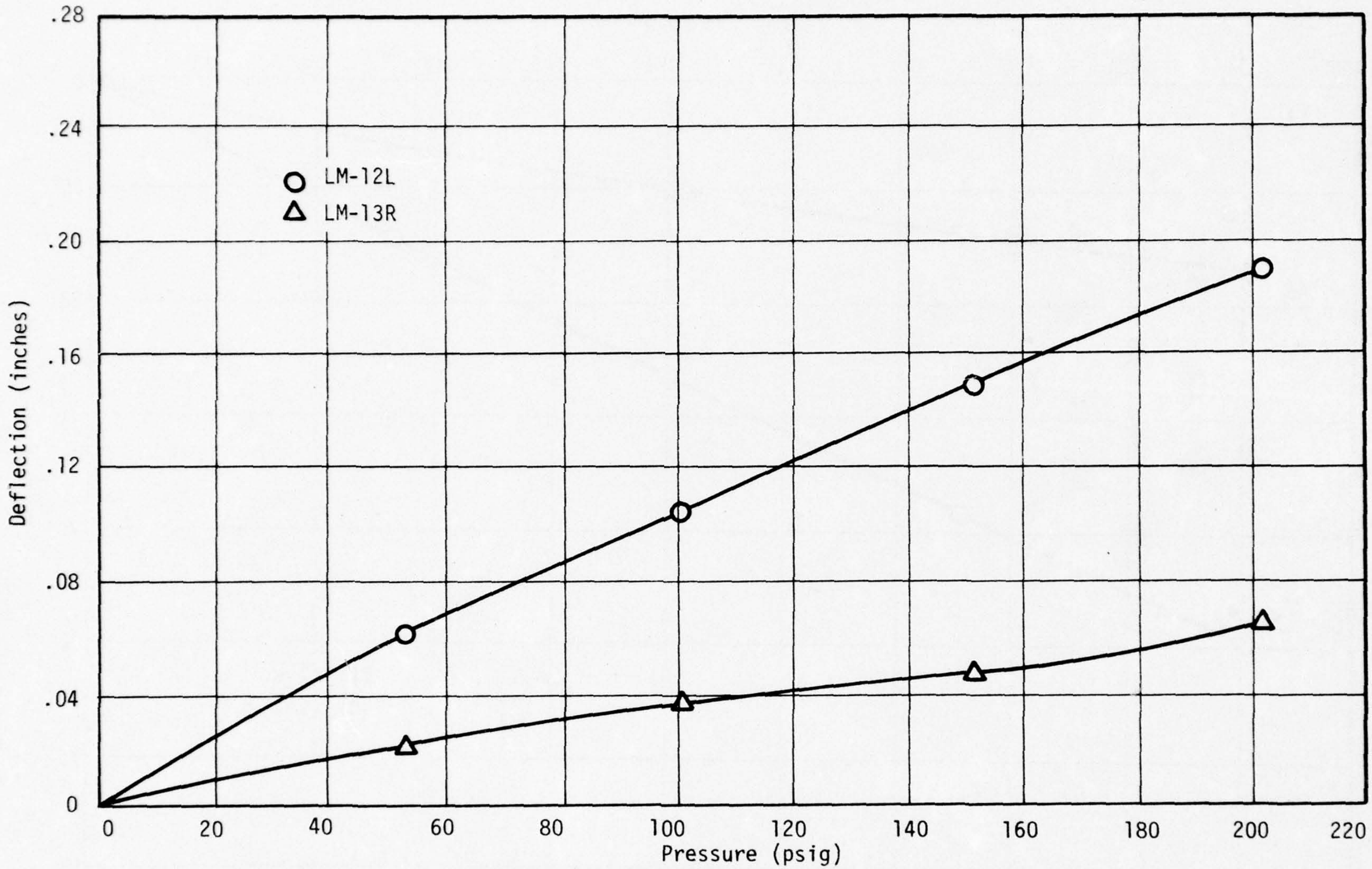


FIGURE C-11. DEFLECTION VS PRESSURE FOR DEVICES LM-12L AND LM-13R

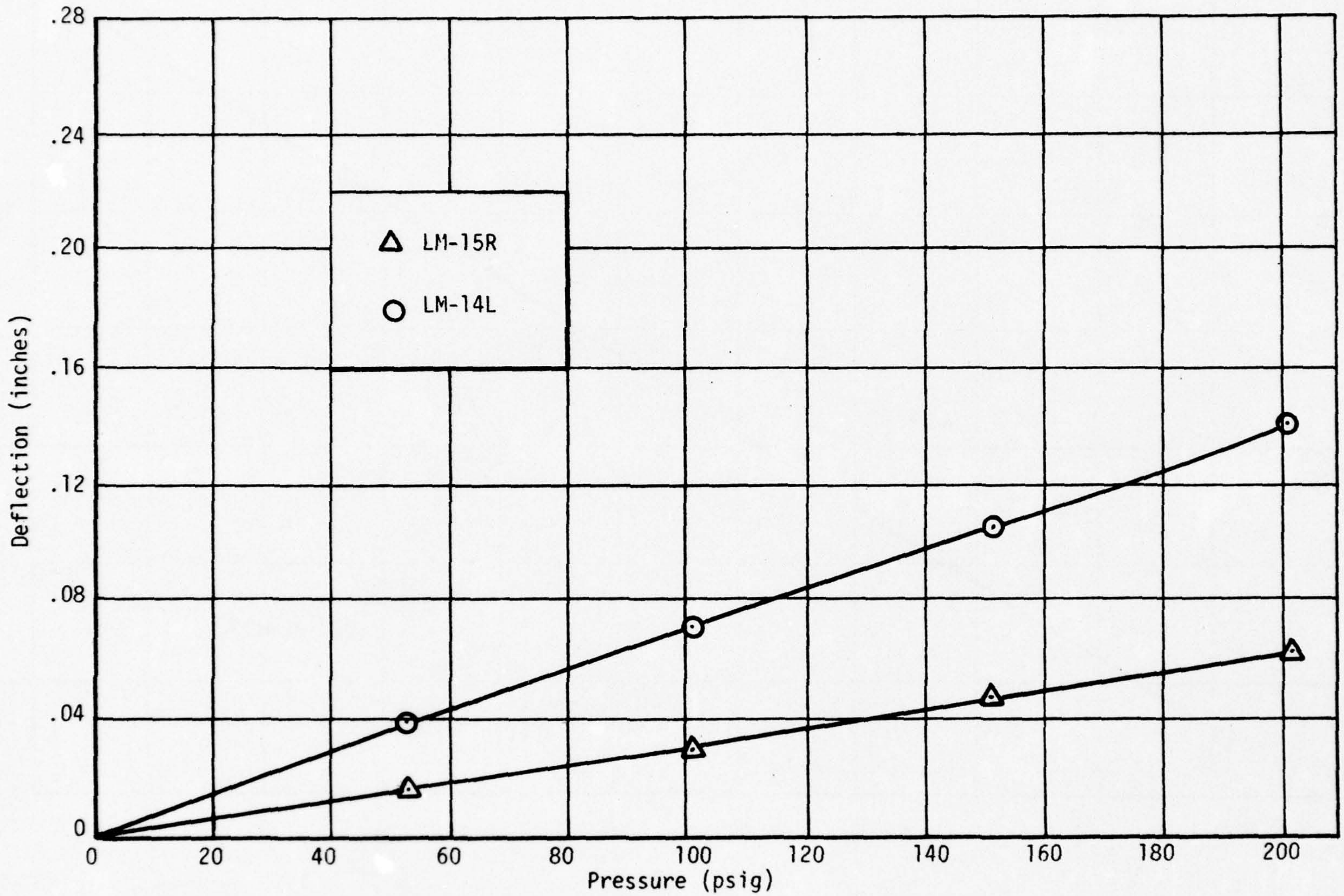


FIGURE C-12. DEFLECTION VS INTERNAL PRESSURE FOR DEFLECTION DEVICES LM-14L & LM-15R

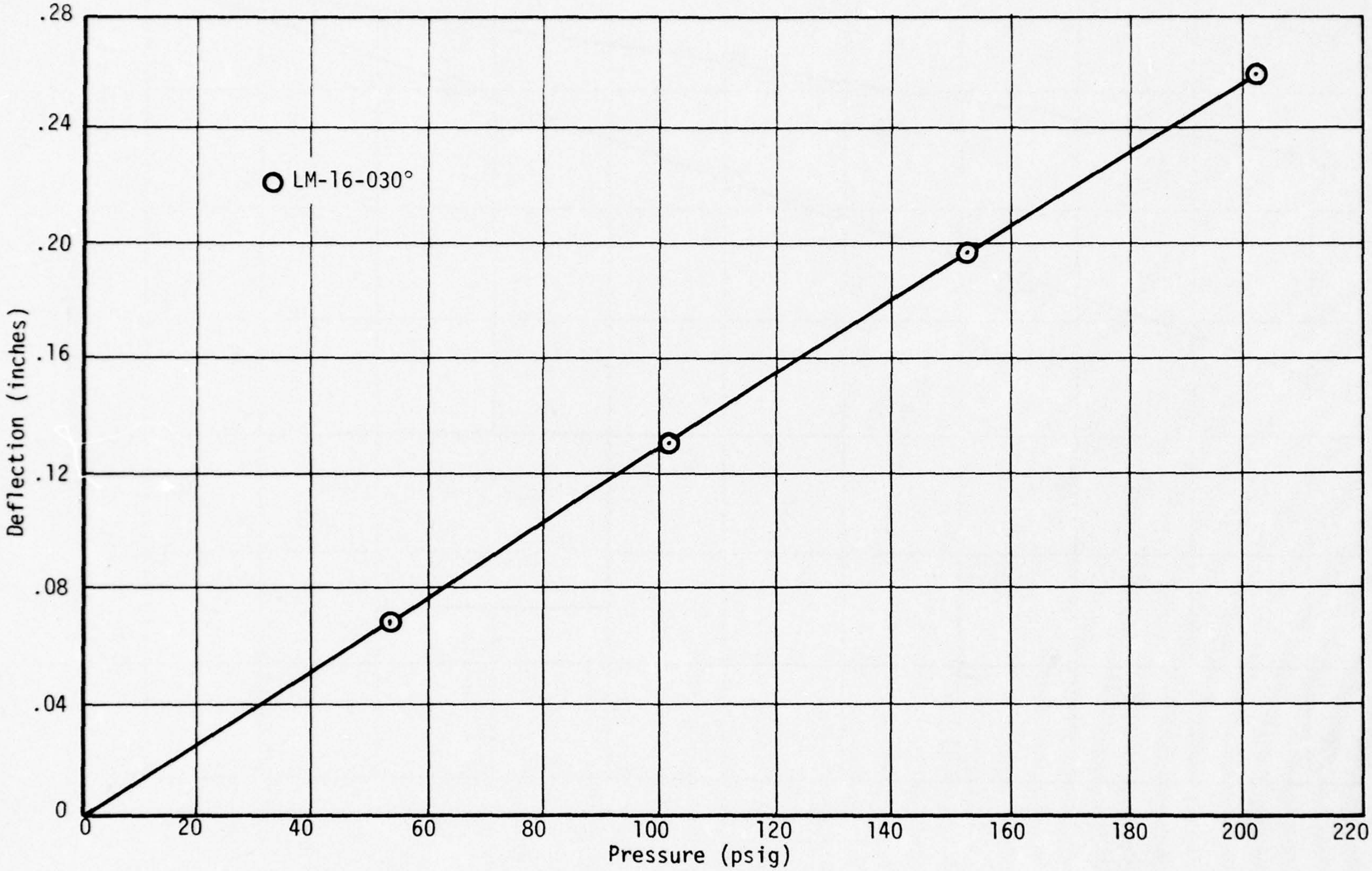


FIGURE C-13. DEFLECTION VS PRESSURE FOR DEVICE LM-16

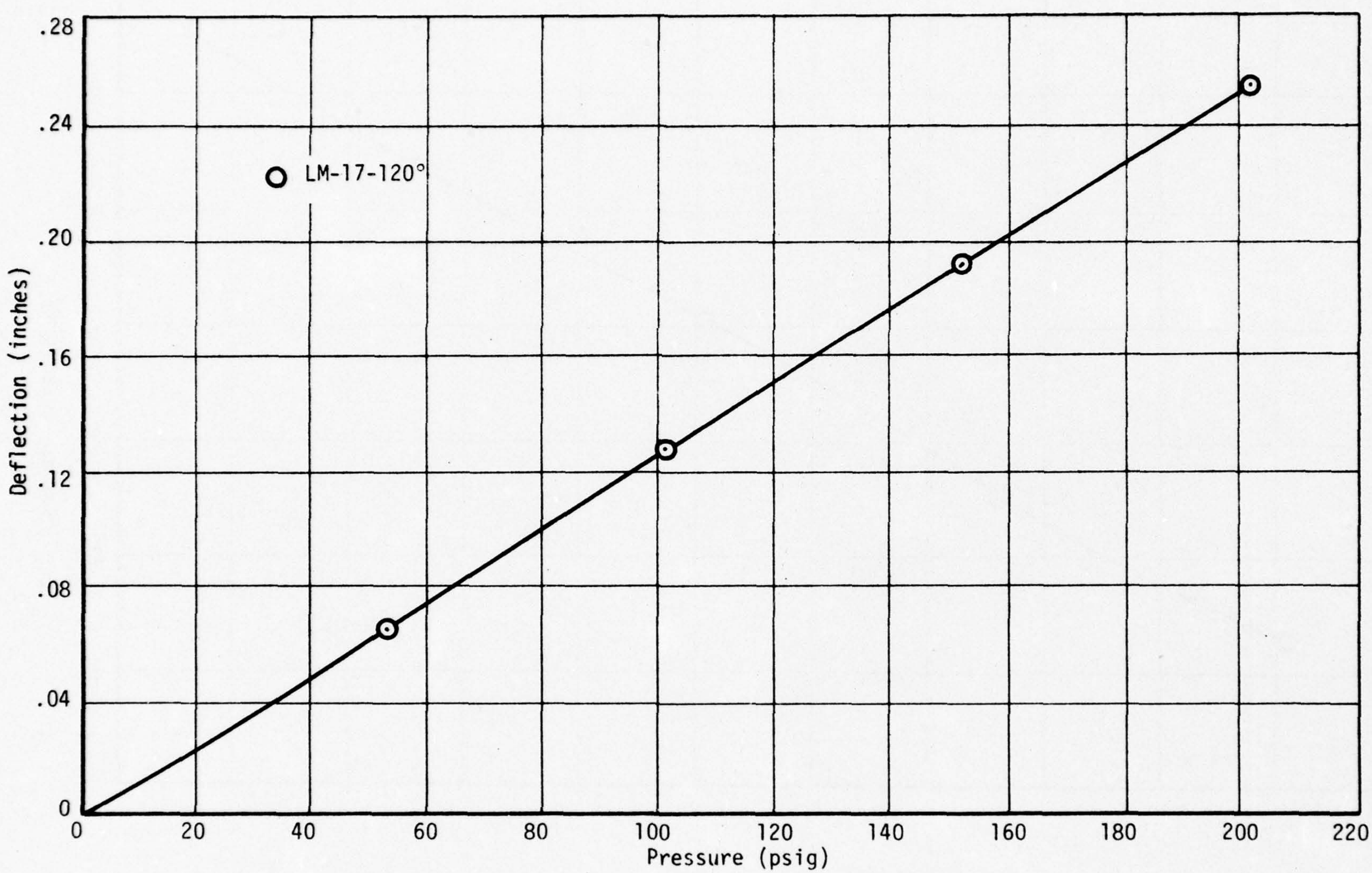


FIGURE C-14. DEFLECTION VS PRESSURE FOR DEVICES LM-17

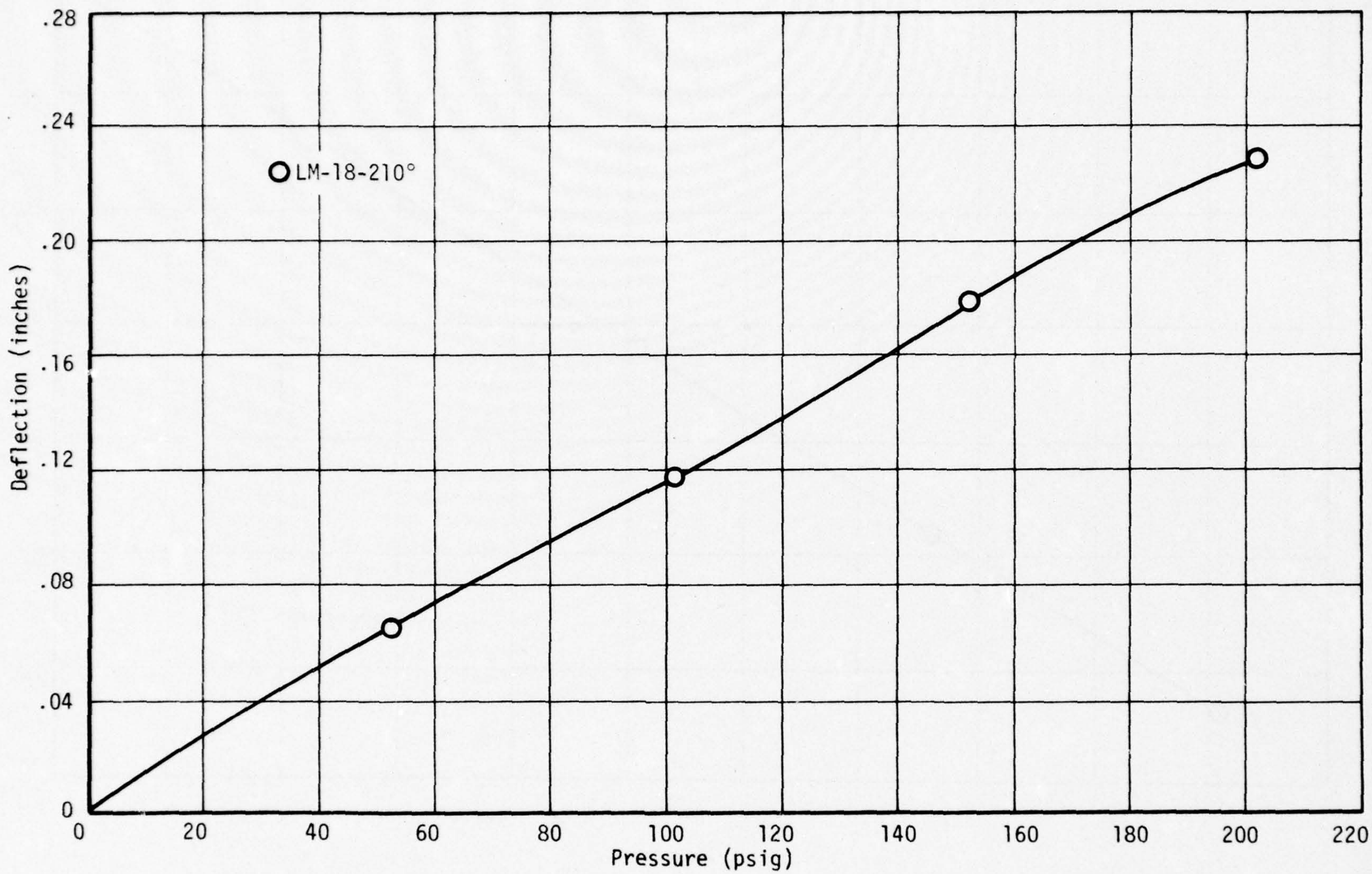


FIGURE C-15. DEFLECTION VS PRESSURE FOR DEVICE LM-18

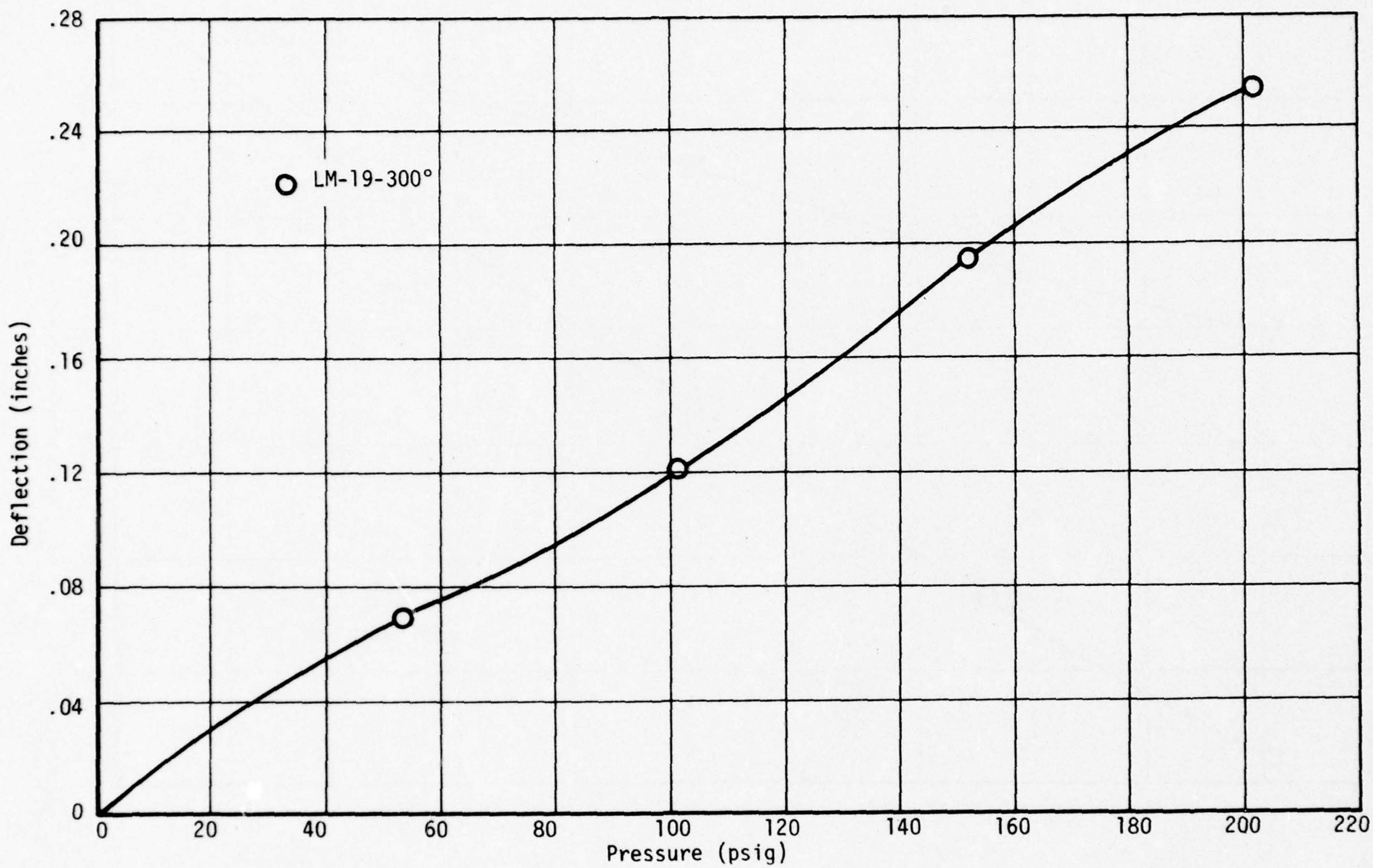


FIGURE C-16. DEFLECTION VS PRESSURE FOR DEVICE LM-19

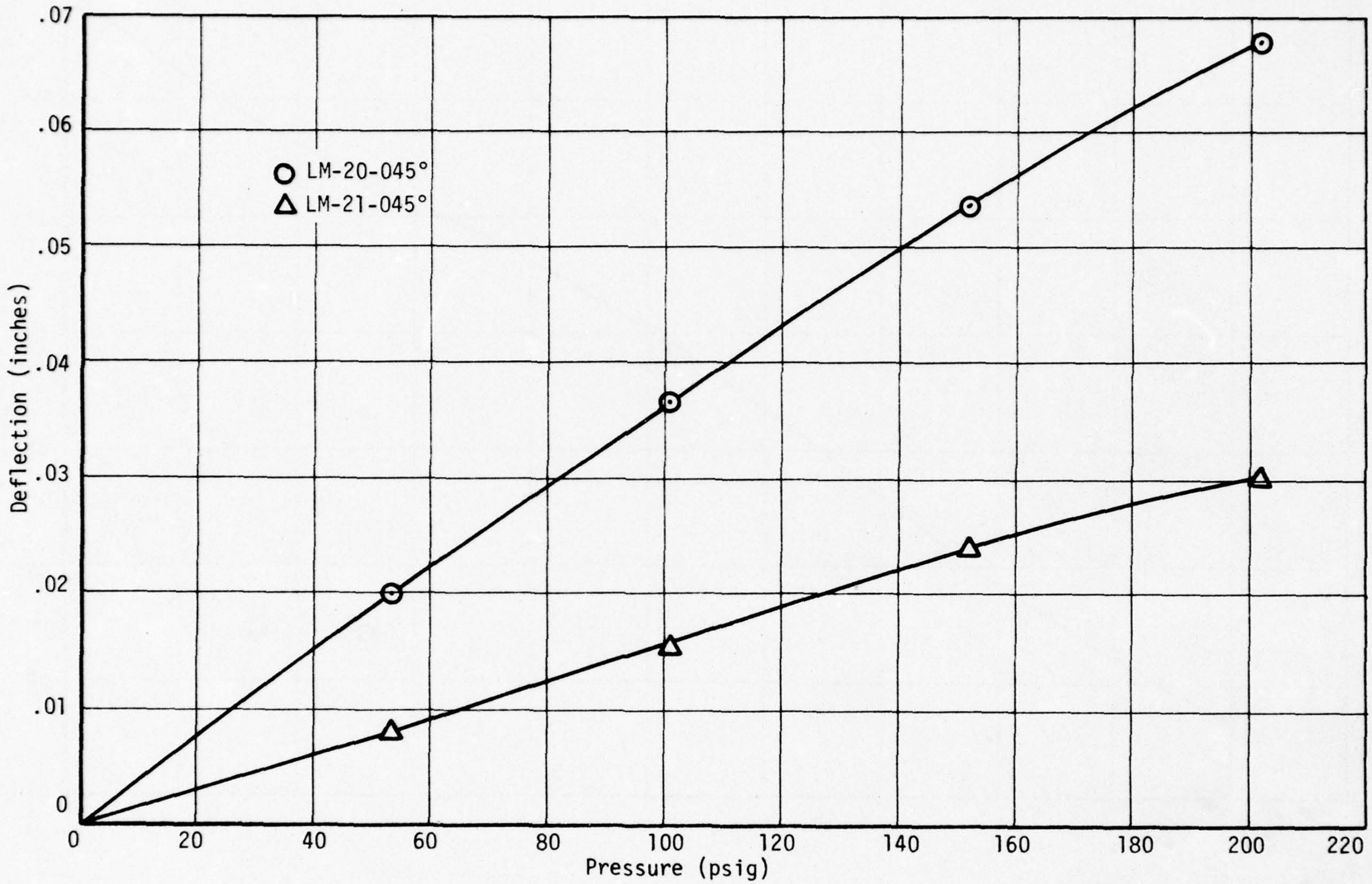


FIGURE C-17. DEFLECTION VS PRESSURE FOR DEVICES LM-20 AND LM-21

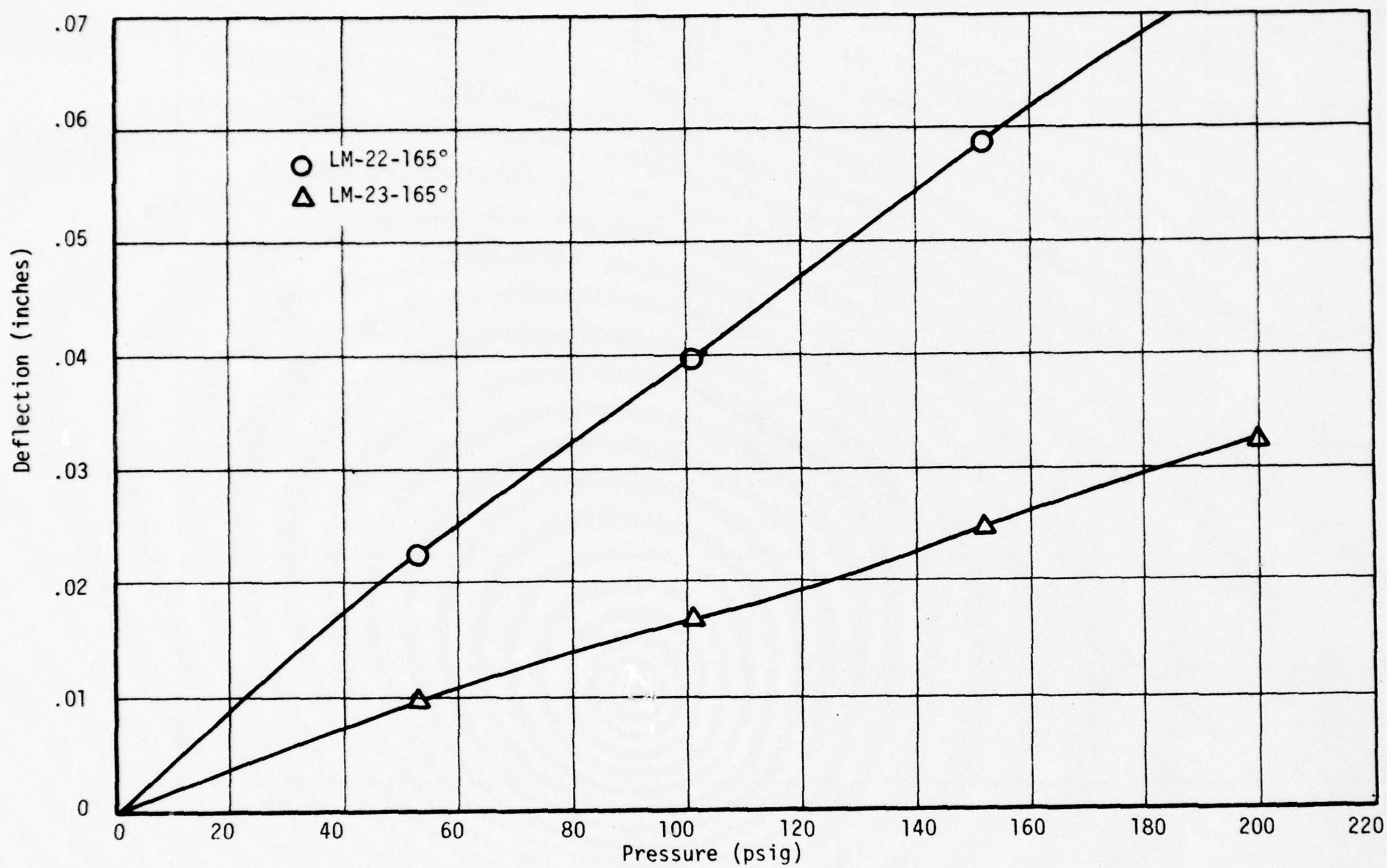


FIGURE C-18. DEFLECTION VS PRESSURE FOR DEVICES LM-22 AND LM-23

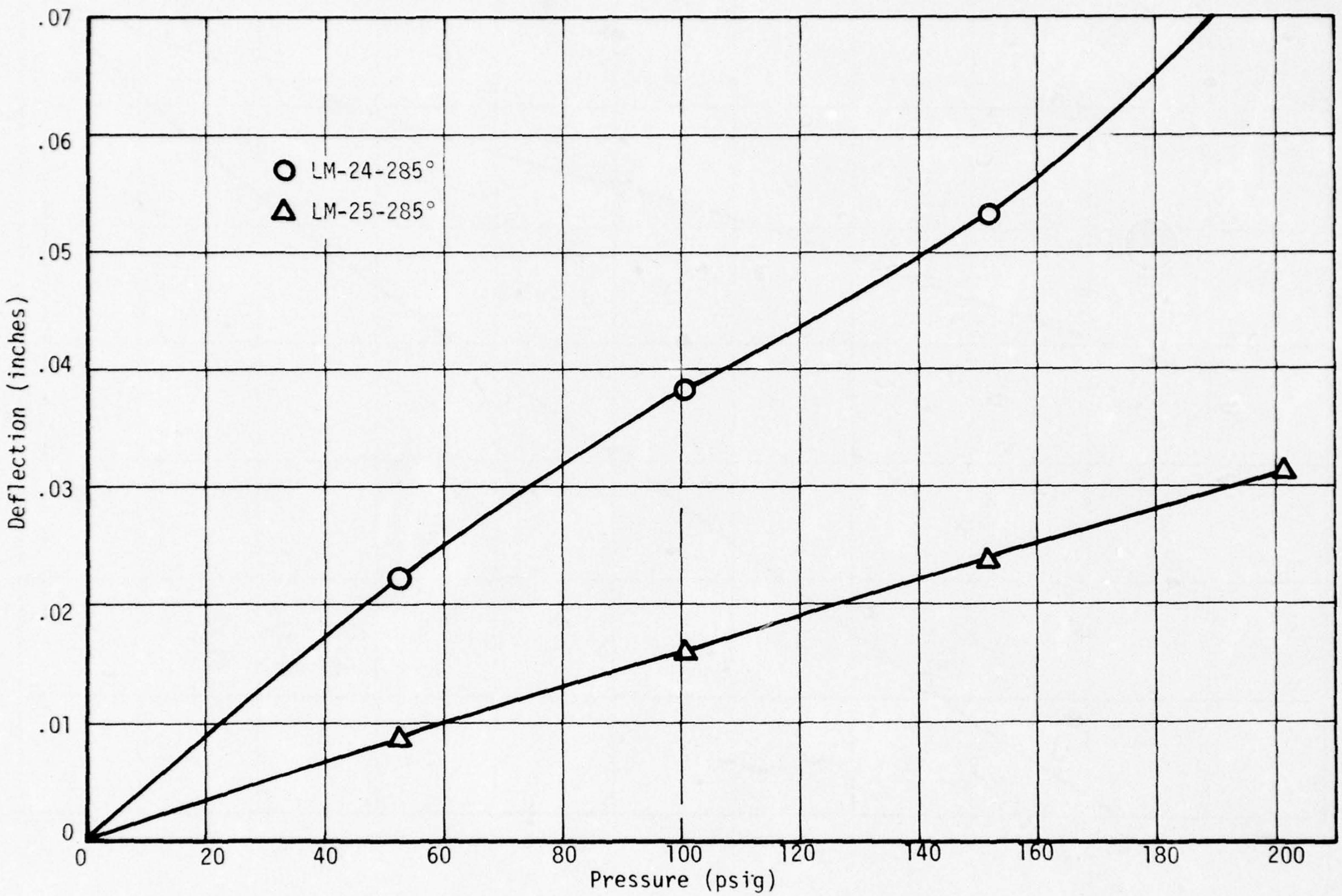


FIGURE C-19. DEFLECTION VS PRESSURE FOR DEVICES LM-24 & LM-25

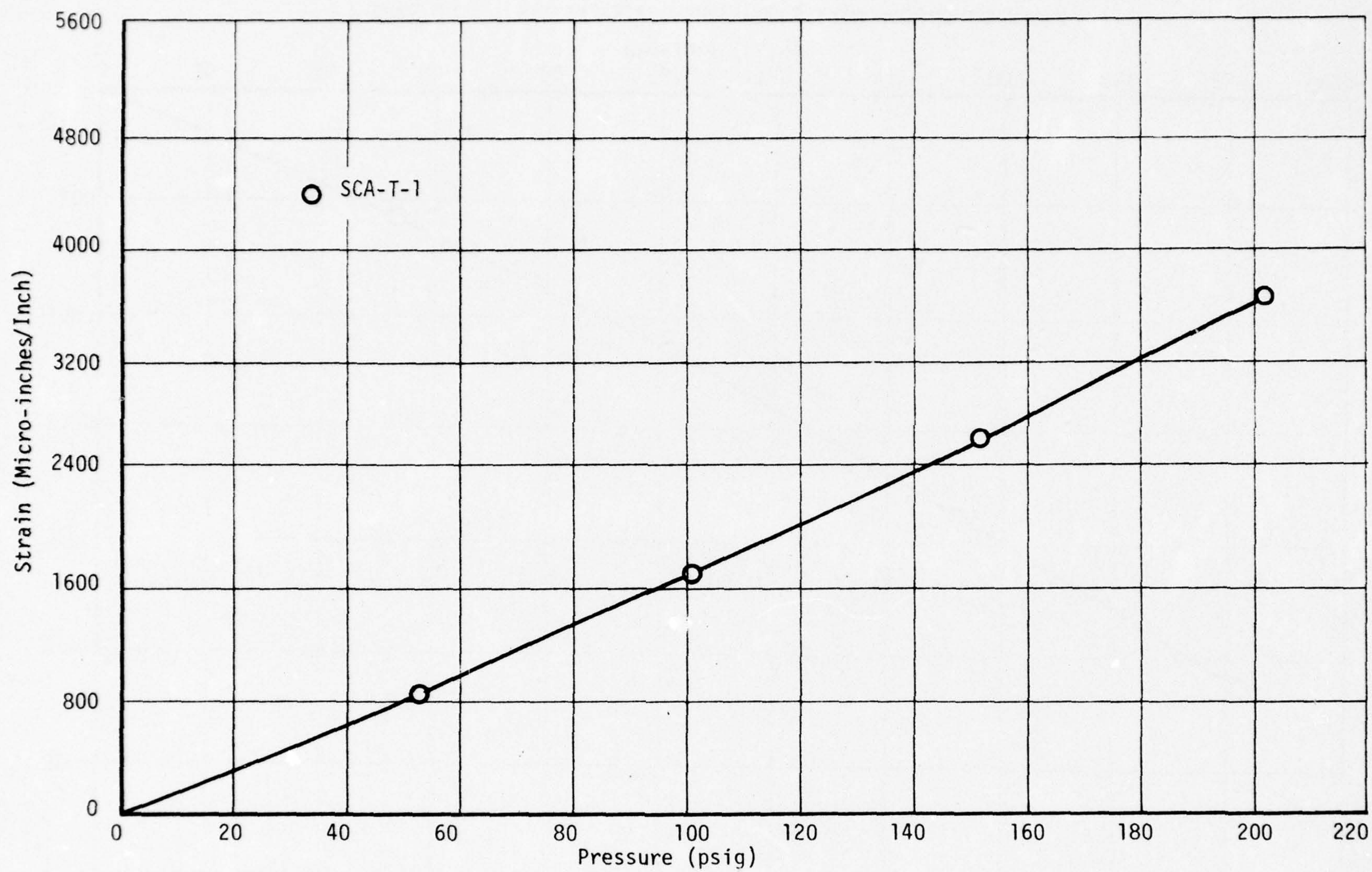


FIGURE C-20. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-1

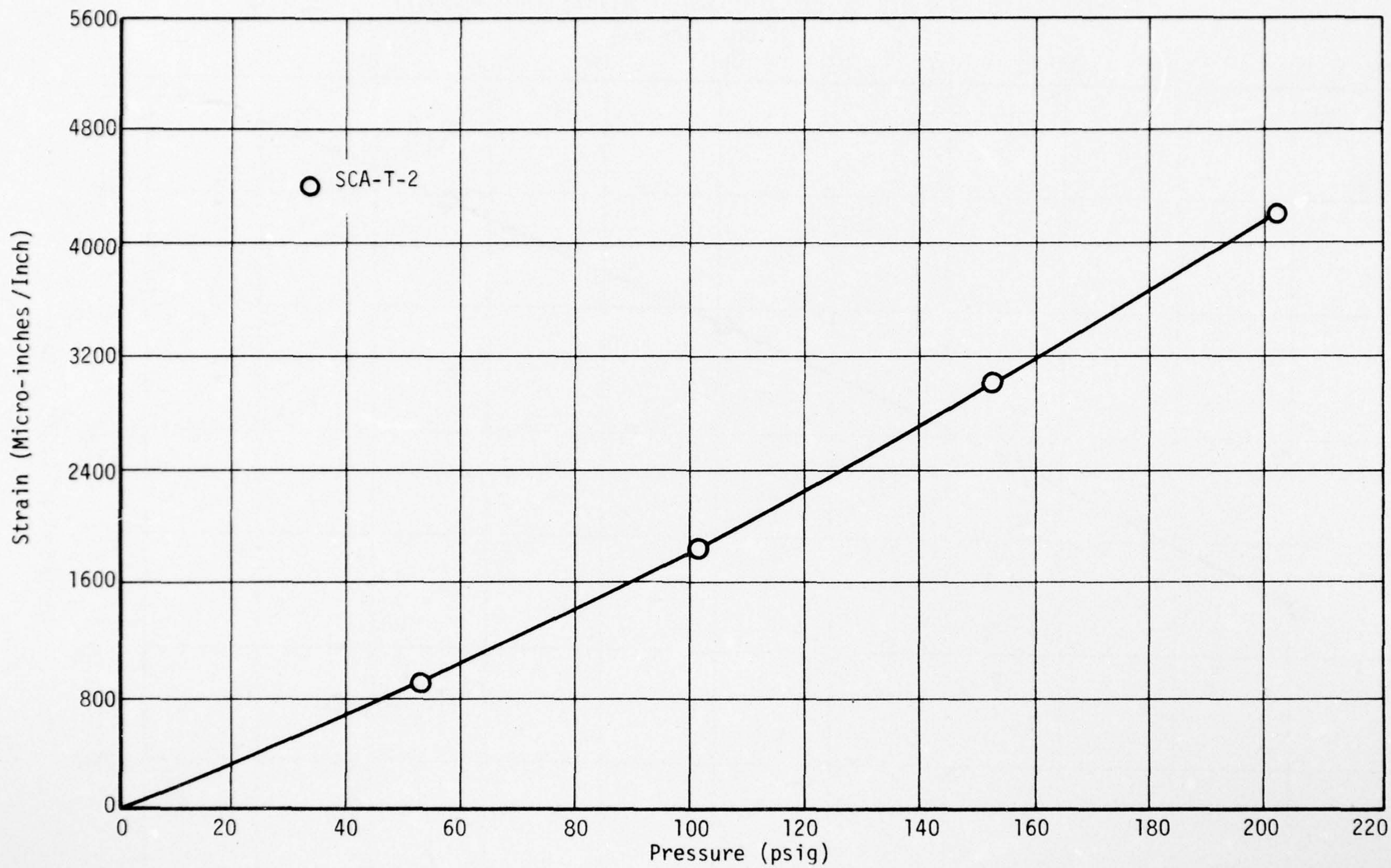


FIGURE C-21. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-2

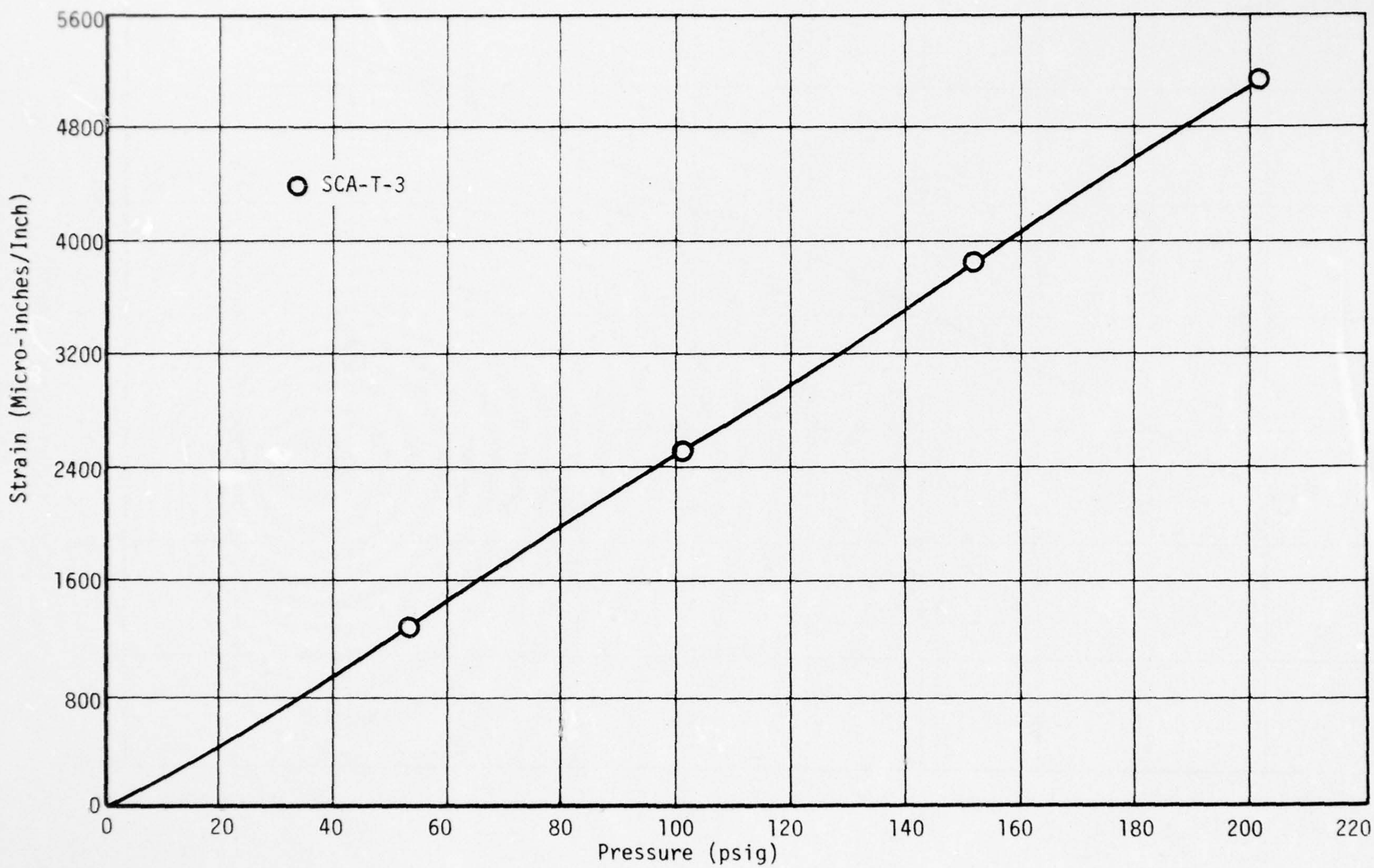


FIGURE C-22. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-3

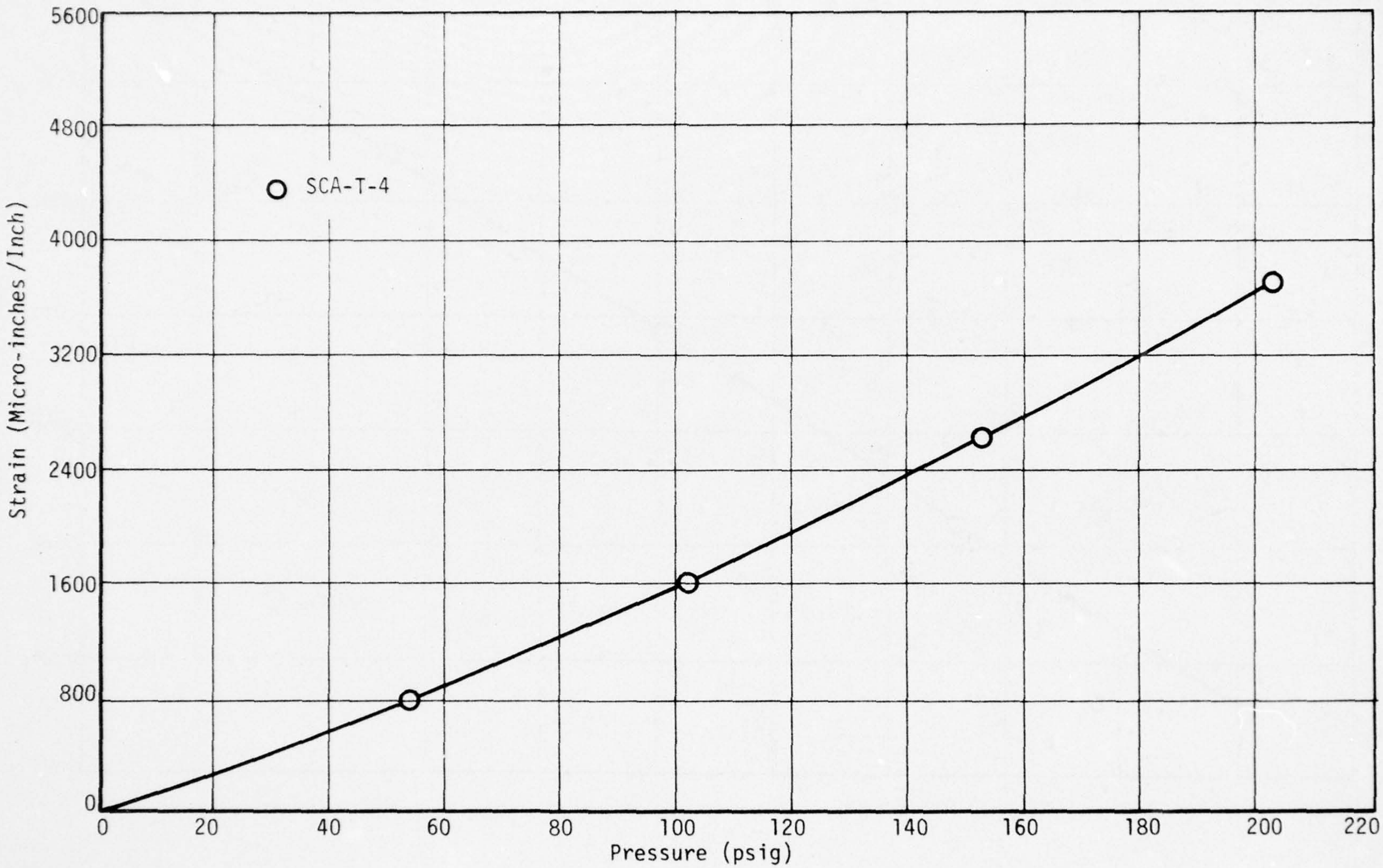


FIGURE C-23. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-4

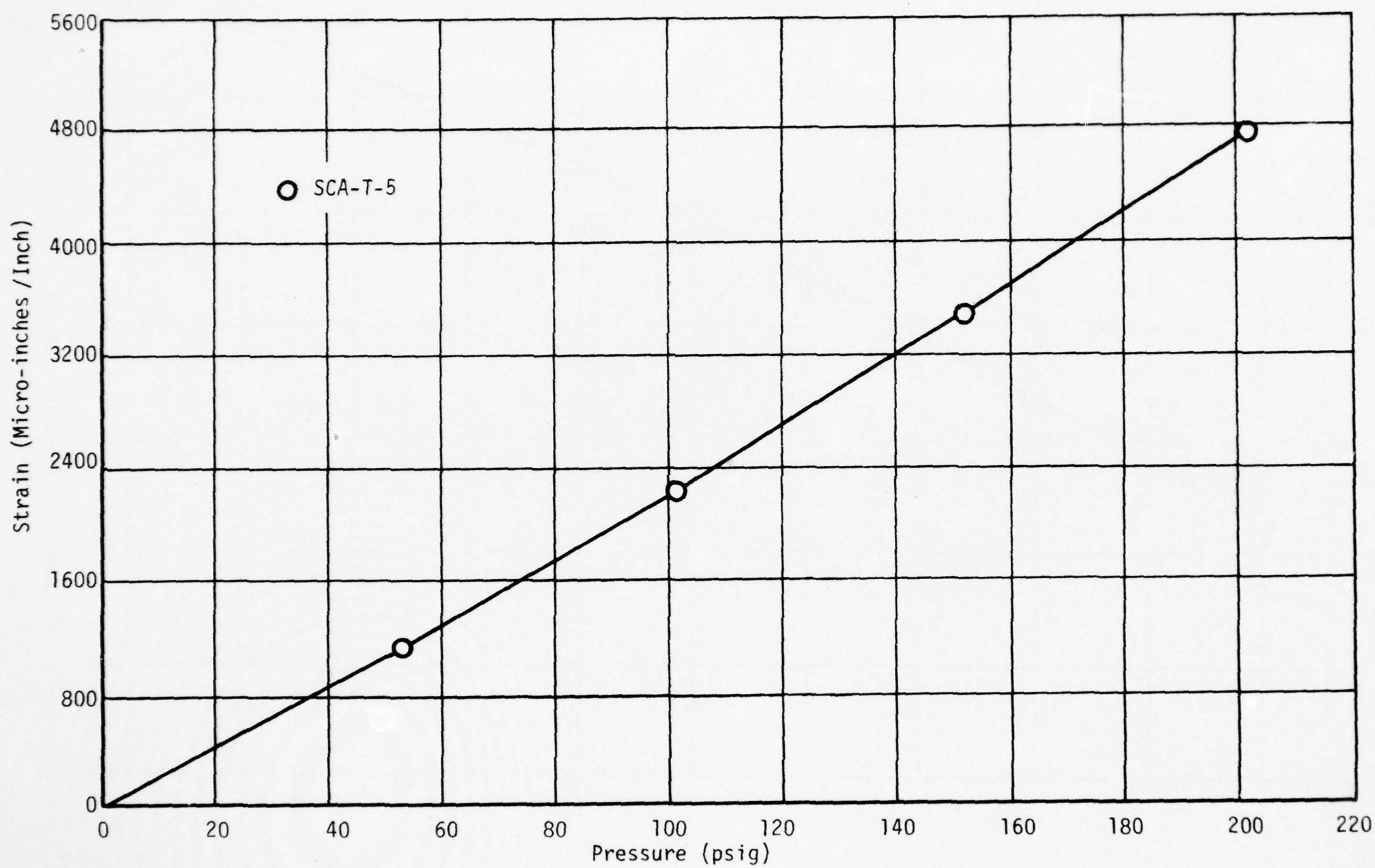


FIGURE C-24. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-5

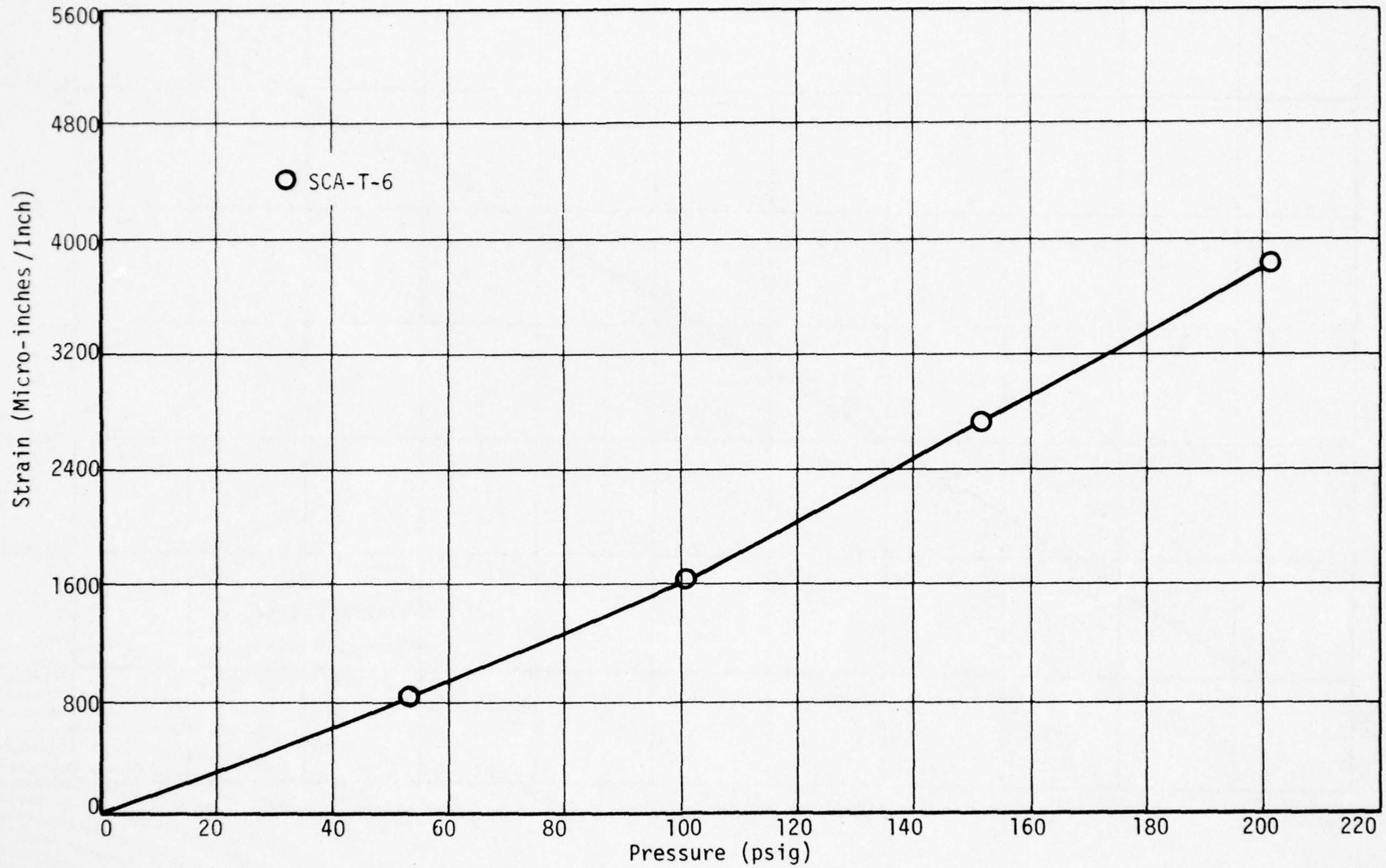


FIGURE C-25. STRAIN VS PRESSURE FOR STRAIN GAGE NO. SCA-T-6

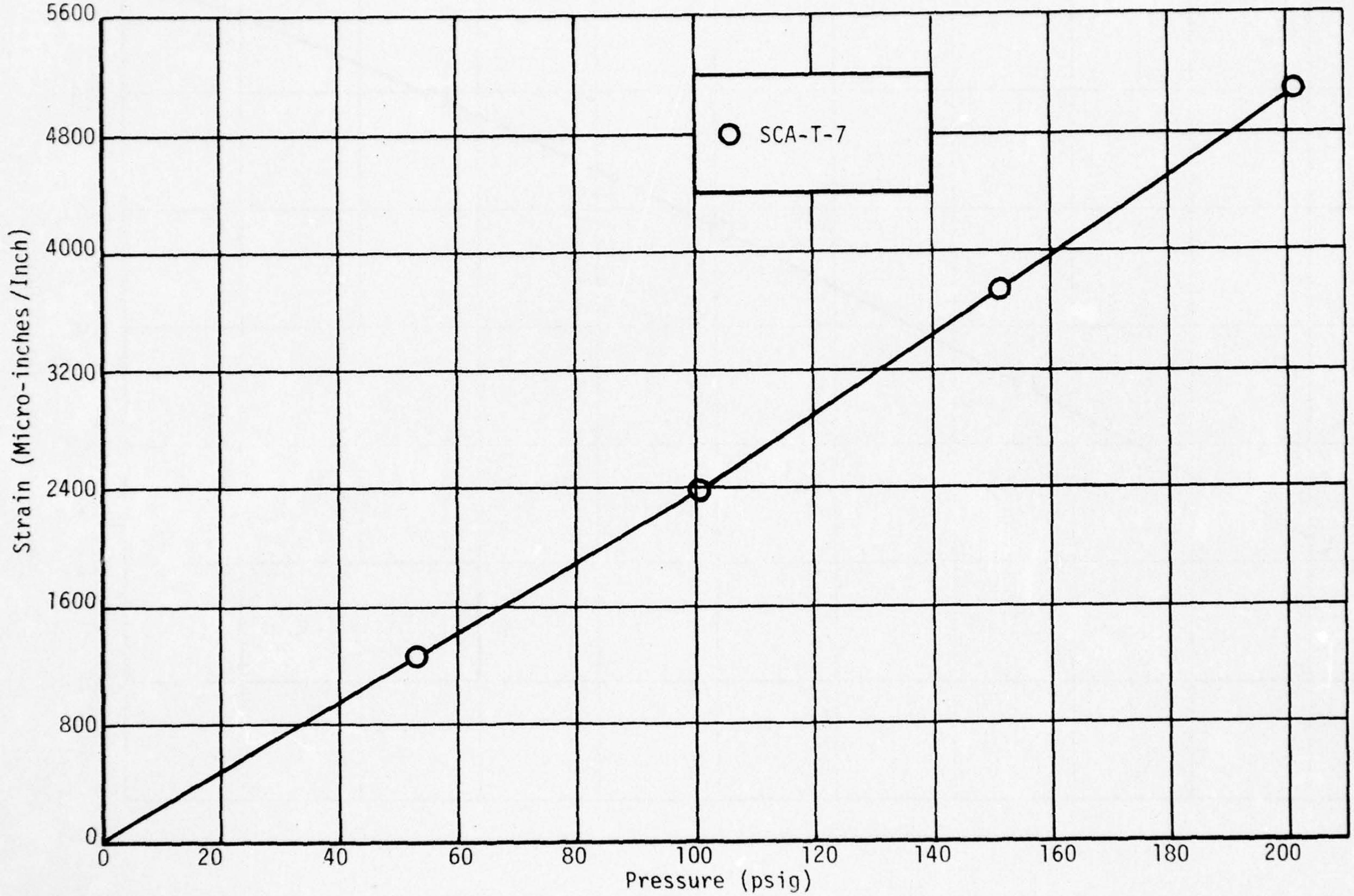


FIGURE C-26. STRAIN VS PRESSURE FOR GAGE NO. SCA-T-7

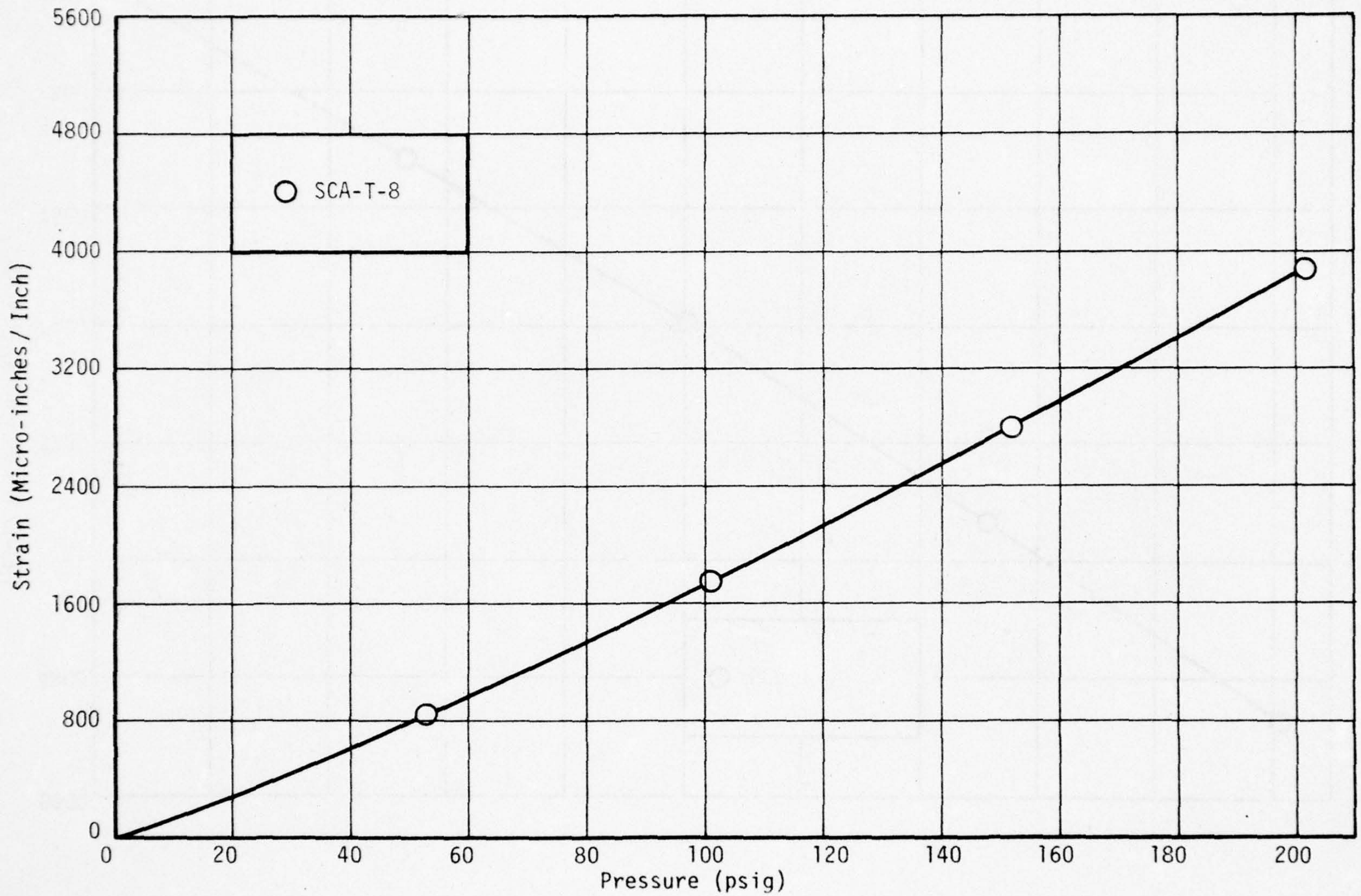


FIGURE C-27. STRAIN VS PRESSURE FOR GAGE NO. SCA-T-8

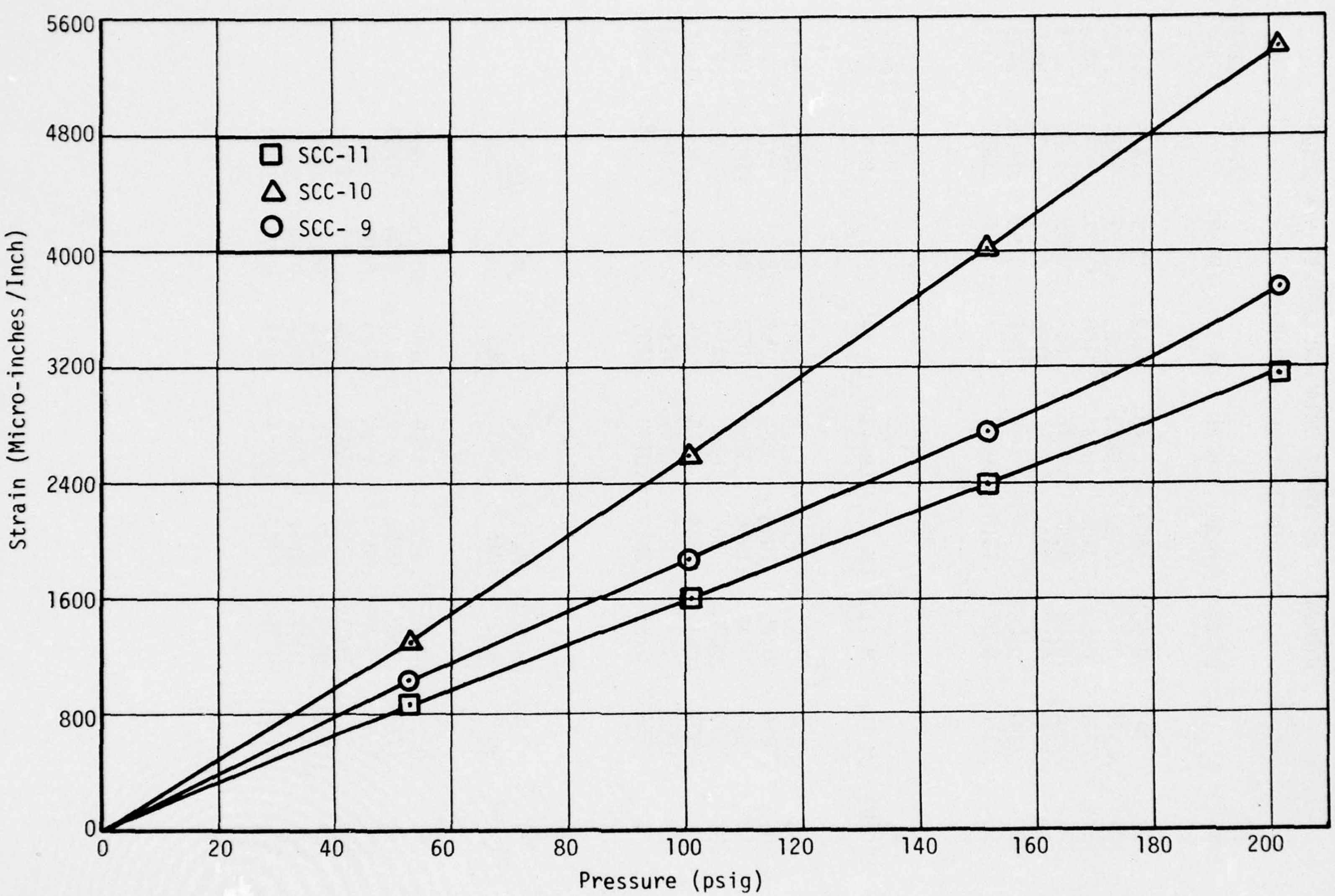


FIGURE C-28. STRAIN VS PRESSURE FOR CIRCUMFERENTIAL GAGES: SCC-9, SCC-10, & SCC-11

TABLE C-1

HYDROTEST RESPONSE DATA FOR CHAMBER S/N 30114

Deflections - Inches

PC (psig)	LM-1L	LM-2R	LM-3L	Lm-4R	LM-5L	LM-6R	LM-7L-120°	LM-8L-240°	LM-9L-0°
53	.1381	.0065	.1409	.0048	.1452	.0128	.1475	.1475	.1375
101	.2428	.0112	.2432	.0089	.2333	.0215	.2475	.2500	.2400
152	.3428	.0158	.3405	.0132	.3159	.0297	.3475	.3428	.3333
202	.4262	.0198	.4048	.0176	.3886	.0365	.4300	.4225	.4238
151	.3381	.0152	.3381	.0125	.3136	.0279	.3425	.3405	.3310
100	.2341	.0105	.2409	.0080	.2286	.0193	.2425	.2405	.2350
50	.1286	.0052	.1318	.0040	.1357	.0107	.1350	.1325	.1475

PC (psig)	LM-10L	LM-11R	LM-12L	LM-13R	LM-14L	LM-15R	LM-16-030°	LM-17-120°	LM-18-210°
53	.0575	.0252	.0619	.0220	.0381	.0165	.0690	.0643	.0643
101	.1050	.0395	.1048	.0381	.0714	.0300	.1310	.1262	.1167
152	.1523	.0548	.1500	.0486	.1050	.0465	.1976	.1909	.1786
202	.1977	.0678	.1905	.0668	.1400	.0620	.2595	.2524	.2286
151	.1523	.0543	.1524	.0515	.1075	.0455	.2024	.1954	.1810
100	.1068	.0391	.1071	.0357	.0738	.0291	.1381	.1333	.1214
50	.0550	.0239	.0619	.0190	.0405	.0145	.0738	.0738	.0667

PC (psig)	LM-19-300°	LM-20-045°	LM-21-045°	LM-22-165°	LM-23-165°	LM-24-285°	LM-25-285°
53	.0690	.0200	.0083	.0228	.0100	.0223	.0087
101	.1214	.0367	.0157	.0400	.0171	.0384	.0160
152	.1952	.0535	.0241	.0590	.0250	.0586	.0241
202	.2548	.0681	.0304	.0745	.0328	.0767	.0316
151	.1976	.0525	.0241	.0571	.0250	.0586	.0232
100	.1357	.0362	.0167	.0396	.0167	.0384	.0152
50	.0738	.0195	.0100	.0224	.0089	.0209	.0078

TABLE C-2

HYDROTEST RESPONSE DATA FOR CHAMBER S/N 30114

PC (psig)	Strain - Microinches/Inch SCAT-1	SCAT-2	SCAT-3	SCAT-4	SCAT-5	SCAT-6	SCAT-7	SCAT-8
53	848	896	1269	783	1125	800	1242	836
101	1695	1858	2504	1600	2233	1617	2367	1736
152	2657	3032	3841	2617	3488	2717	3726	2780
202	3668	4238	5127	3701	4760	3834	5099	3873
151	2706	3097	3959	2734	3619	2784	3857	2828
100	1728	1956	2741	1750	2461	1767	2586	1800
50	831	945	1506	867	1320	850	1344	868

PC (psig)	SCC-9	SCC-10	SCC-11
53	1015	1306	864
101	1861	2581	1597
152	2741	4012	2380
202	3553	5411	3146
151	2758	4012	2396
100	1895	2581	1630
50	1015	1275	864

TABLE C-3

SUMMARY RESPONSE DATA FOR CHAMBER S/N 30114

Hoop Strains at Barrel Section (Micro-inches/inch)		Pressure, psig 0	53	101	152	202
Forward Equator		0	1015	1861	2741	3553
Mid Barrel		0	1306	2581	4012	5411
Aft Equator		0	864	1597	2380	3146
Fwd Dome Deflections (inches)						
7.1 Radius	Longitudinal	0	.1381	.2428	.3428	.4262
	Radial	0	.0065	.0112	.0158	.0198
10.5 Radius	Longitudinal	0	.1409	.2432	.3405	.4048
	Radial	0	.0048	.0089	.0132	.0176
14.3 Radius	Longitudinal	0	.1452	.2333	.3159	.3886
	Radial	0	.0128	.0215	.0297	.0365
Aft Dome Deflection (inches)						
14.3 Radius	Longitudinal	0	.0525	.1050	.1523	.1977
	Radial	0	.0252	.0395	.0548	.0678
17.0 Radius	Longitudinal	0	.0619	.1048	.1500	.1905
	Radial	0	.0220	.0381	.0486	.0668
19.9 Radius	Longitudinal	0	.0381	.0714	.1050	.1400
	Radial	0	.0165	.0300	.0405	.0620

APPENDIX D

CALIBRATION DATA OF THE STRESS GAGES USED IN MOTOR NO. 1

CALIBRATION DATA OF THE STRESS GAGES USED IN MOTOR NO. 1

A. NORMAL STRESS GAGE CALIBRATION DATA

The normal stress transducers, Konigsberg Instruments, Inc. Models P14EB-SC-150 and P14EB-SC-450 were calibrated and temperature compensated by the supplier at the rated full scale pressure ranges of 150 and 450 psig, respectively, and at +30°, +80° and +130°F. They were then encapsulated with inert liner material (IBT-115) and the final bench pressure calibration and temperature compensation were performed. The manufacturer's bench calibration results for the normal stress gages are contained in the documentary files. However, a typical normal stress gage calibration data sheet is given in Table D-1. The ASPC code designation which corresponds to Konigsberg Instrument normal gage serial numbers are given in Table D-2. Table D-3 summarizes the normal gage sensitivity and zero readings at three different temperatures, 30°, 77° and 130°F. These values represent the gage calibration parameters which were originally used for the reduction of data taken on Motor No. 1.

After receipt at ASPC the gages were subjected to further calibrations, both in the laboratory and after installation in the motor.

To insure that the gages were operating in the tensile mode and that the gages were connected properly, they were calibration tested under vacuum. That is, the gages were placed in a vacuum jar, one at a time, at a temperature of 77°F $\pm$ 3°F and tested in pressure increments (5 psi) to 10^{-2} Torr. Figure D-1 contains typical vacuum calibration curves for Gages N4-1 and N4-2. Similar calibration curves for the rest of the normal gages are in the documentary files.

B. SHEAR STRESS GAGE CALIBRATION DATA

The shear gages, designated Konigsberg Instruments Model H-2A, were fabricated by Konigsberg Instruments, Inc.. The ASPC shear gage code designation which corresponds to Konigberg's Instrument serial numbers is given in Table D-4.

The fabrication and calibration procedures used were discussed extensively in the STV Report, AFRPL-TR-75-7.

The shear gages were cast and molded into the test fixture shown in Figure D-2. Then calibrated in an Instron Tensile Machine with a wrap-around, temperature conditioning chamber. The outputs of the shear gages were recorded directly onto an X-Y plotter. The first calibration series consisted of applying the load at a constant displacement rate onto the shear fixture, which contained 4 to 6 individual shear gages. Then the tests were repeated with the shear fixture inverted. Then constant strain rate calibration in the initial and "inverted" position were conducted at temperatures of 30°, 77°, and 130°F. Figures D-3 and D-4 provide the constant strain rate calibration curves for shear gage Nos. 10 and 12. The resulting calibration parameters are summarized in Table D-3.

To determine the effects of normal stress on gage response, constant strain rate calibrations were performed on the shear gages at 77°F by gripping the wooden test fixture and pulling normal to it. To assure that the gages

would perform properly for the pressurization tests, constant strain rate shear tests with a superimposed hydrostatic pressure of 25 psi were performed. The normal response and the superimposed hydrostatic calibrations for shear gages No. 10 and 12 are given in Figures D-5 and D-6. All shear calibration curves are contained in the documentary files.

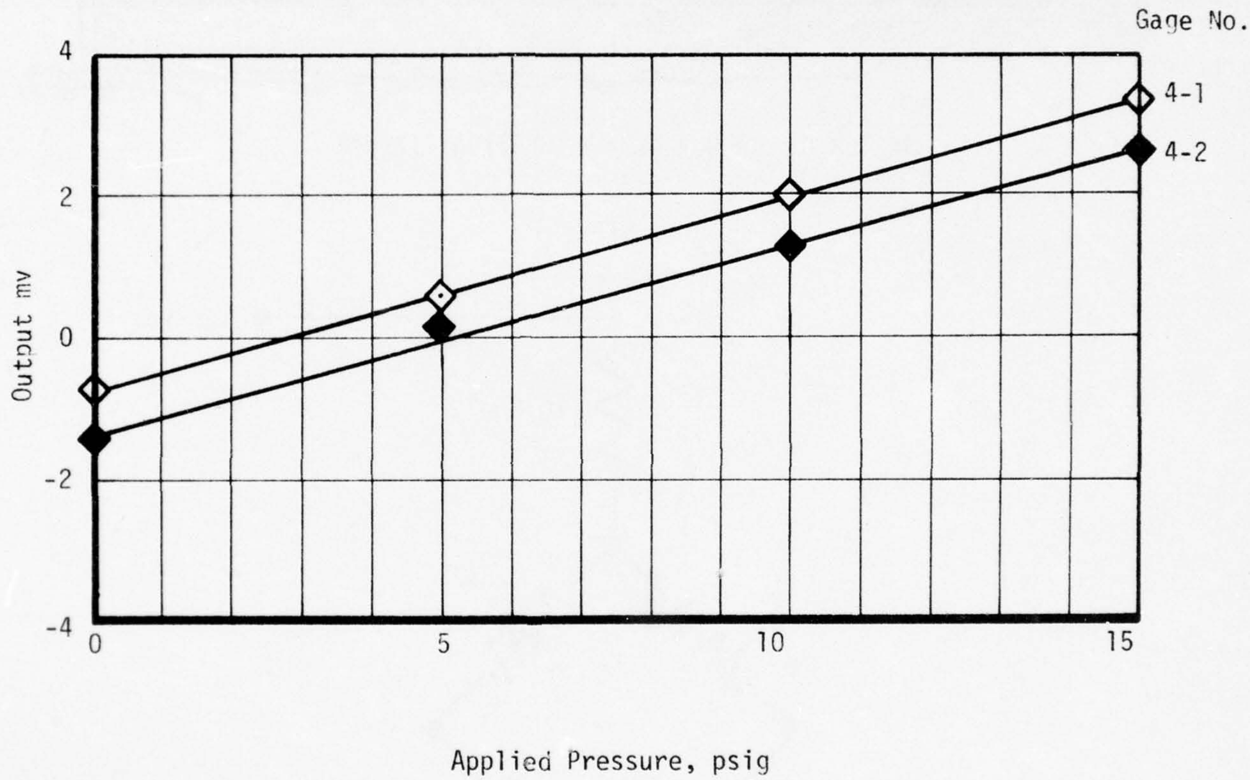
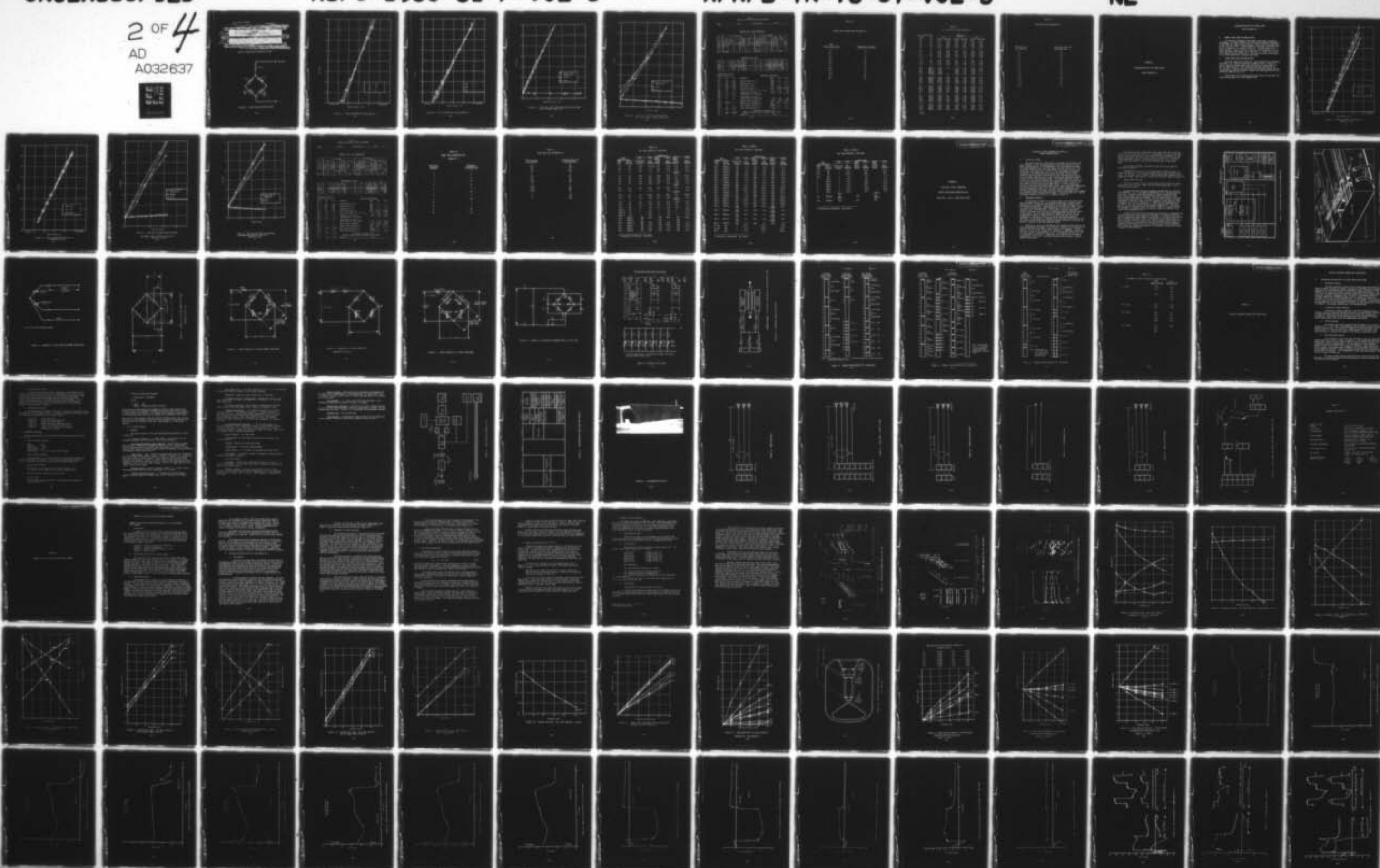
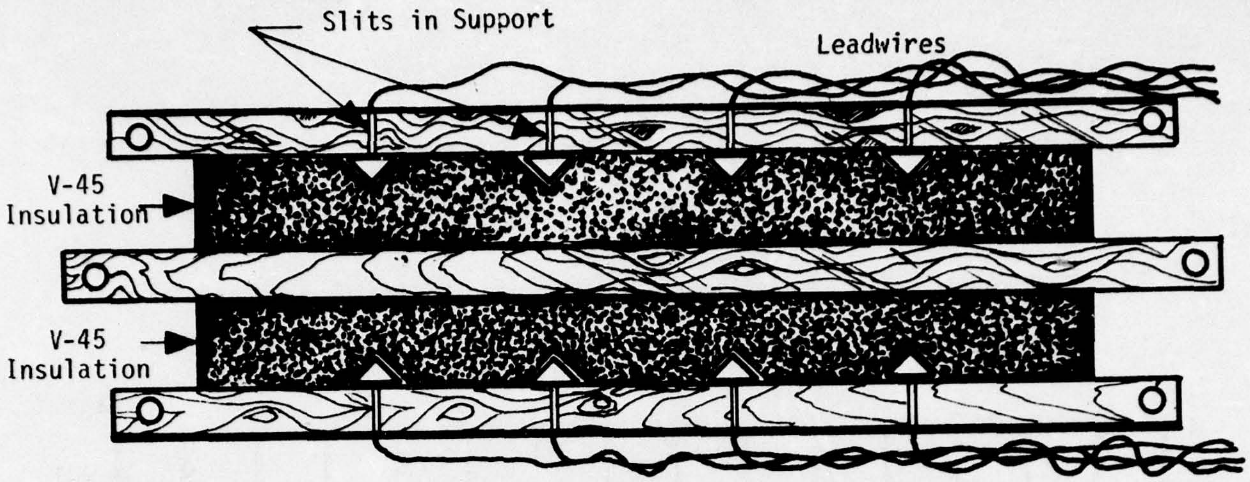


FIGURE D-1. PRESSURE CALIBRATION RESULTS FOR 450 PSI GAGES NOS. 4-1 AND 4-2 INSTALLED IN FULL SCALE MOTOR NO. 1; PRIOR TO CASTING

AD-A032 637 AEROJET SOLID PROPULSION CO SACRAMENTO CALIF F/G 21/9.2
FLEXIBLE CASE-GRAIN INTERACTION IN BALLISTIC WEAPON SYSTEMS. VO--ETC(U)
OCT 76 K W BILLS, S W JANG, H LEEMING F04611-72-C-0055
UNCLASSIFIED ASPC-1953-81-F-VOL-3 AFRPL-TR-76-57-VOL-3 NL

2 OF 4
AD
A032637





SKETCH OF SHEAR GAGE CALIBRATION FIXTURE

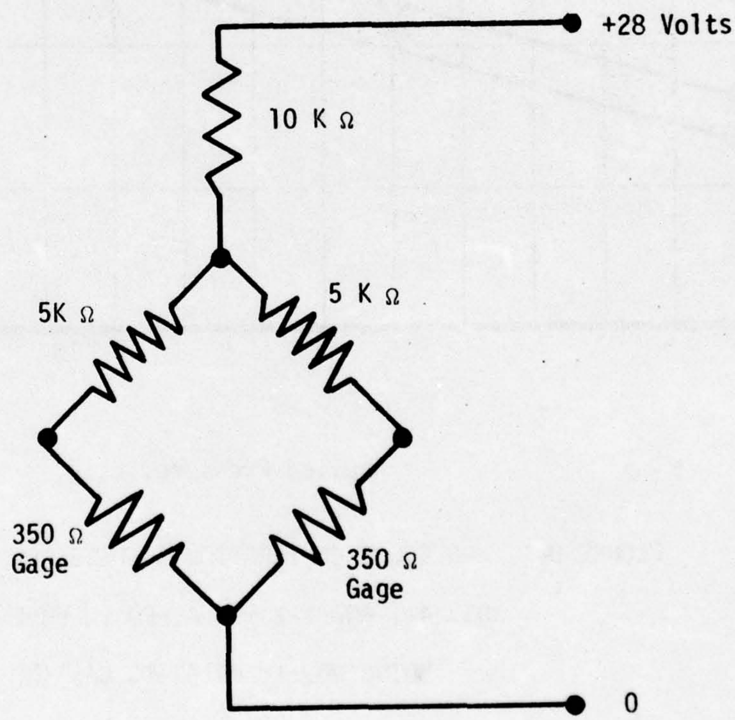


FIGURE D-2. SHEAR GAGE ELECTRICAL CIRCUIT

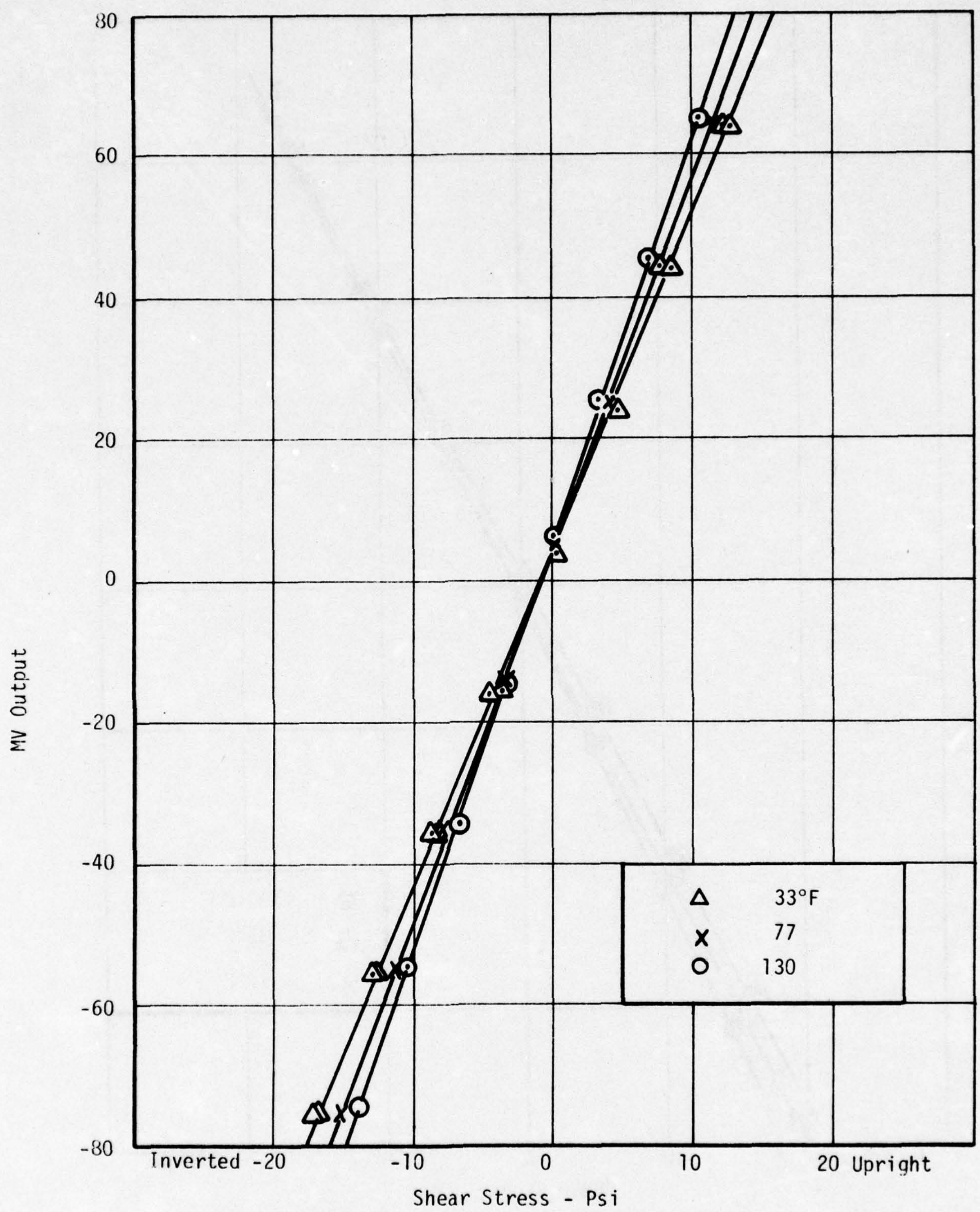


FIGURE D-3. SHEAR CALIBRATION OF SHEAR GAGE NO. 10

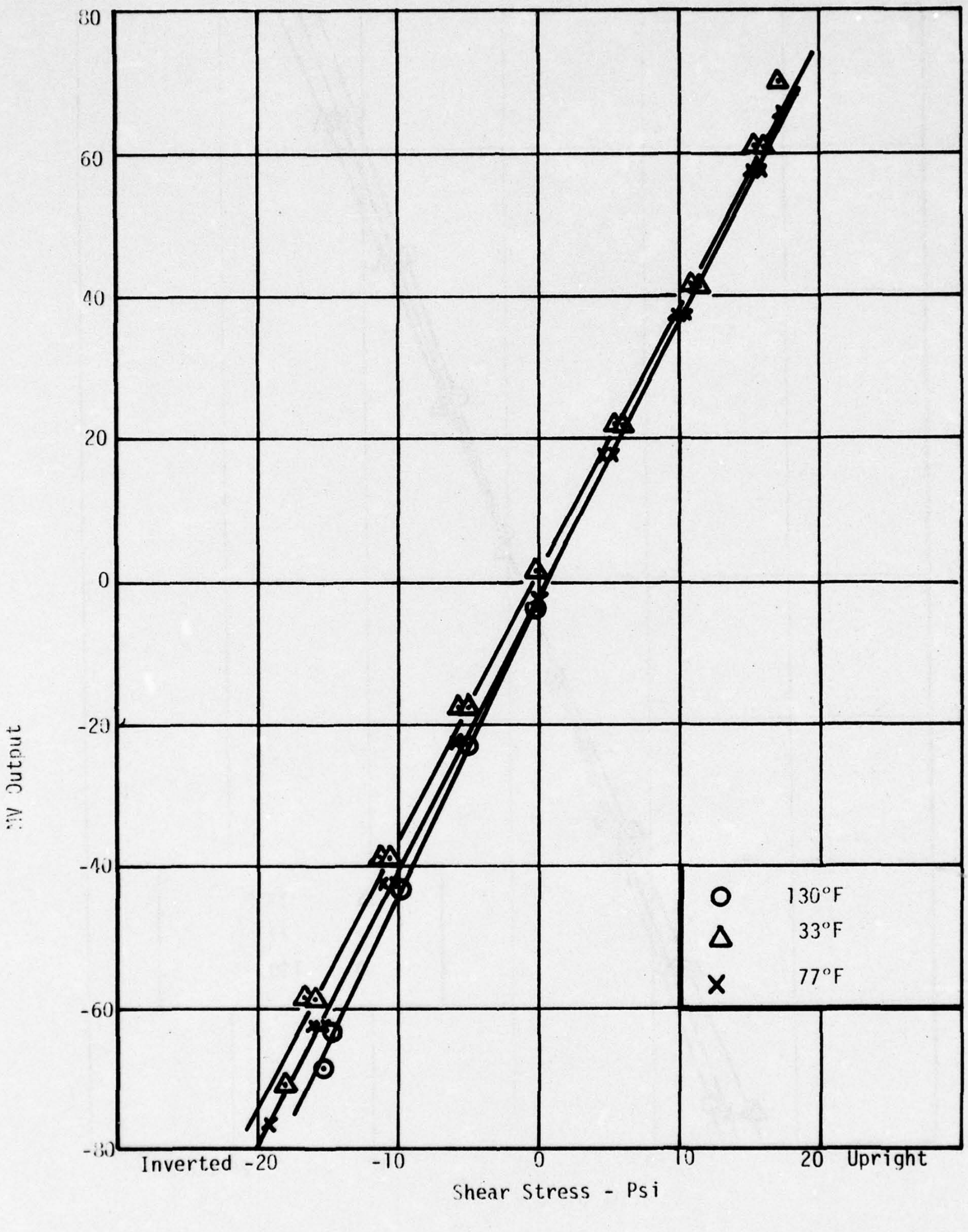


FIGURE D-4. SHEAR CALIBRATION OF SHEAR GAGE NO. 12

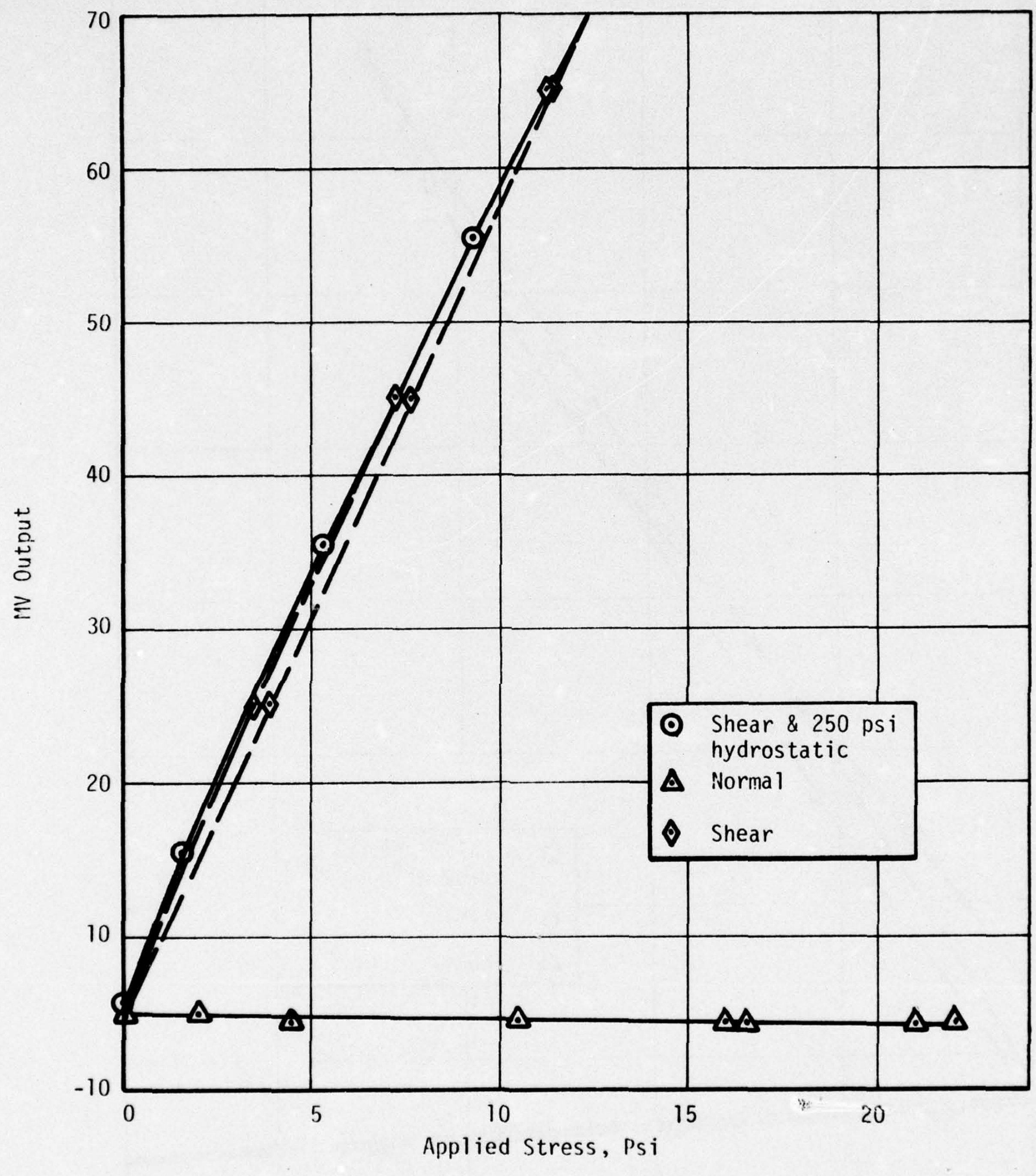


FIGURE D-5. SHEAR GAGE CALIBRATION UNDER PRESSURE AND NORMAL STRESS RESPONSE; GAGE NO. 10

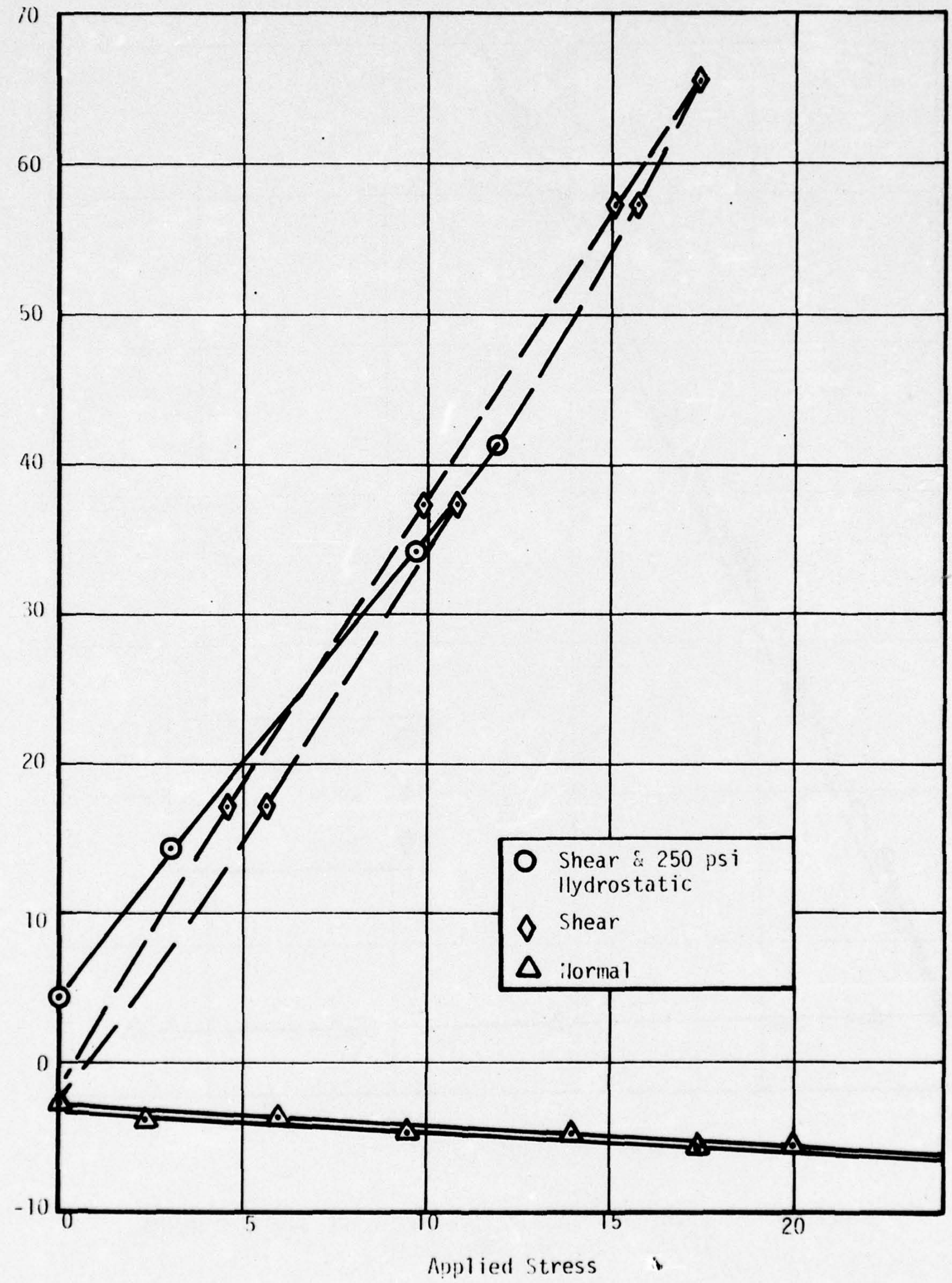


FIGURE D-6. SHEAR GAGE CALIBRATION UNDER PRESSURE AND NORMAL STRESS RESPONSE GAGE NO. 12

TABLE D-1
VENDOR OBSERVATIONS OF GAGE CALIBRATIONS

Model__________ Serial__________ Calibrated By__________ Date__________

AMBIENT TEMP. STATIC ERROR BAND

PSI	1 Half Bridge					2 Half Bridge				
	Eo (mv)			Theo.	Dev'n.	Eo (mv)			Theo.	Dev'n
0	+.90	+.84	↓	+.90	-.06	+2.10	+2.01	↓	+2.10	-.09 ε
112.5	31.52	31.42	-	31.65	-.23	32.84	33.73	-	32.67	+.17
225	62.44	62.37	62.38	62.40	-.03 +.04	63.64	63.53	63.70	63.24	+.40
337.5	92.03		-	93.15	-.12	94.32		-	93.81	+.51
450										
		↑					↑			
F.S.O.	123.00				Σ.27	122.28				Σ.60

TEMPERATURE TEST DATA

PSI °F		30	80	130				30	80	130
0		+1.24	+.53	+1.08				-.18	-.29	-.34
150		41.78	41.53	41.68				40.88	40.47	40.21
F.S.O.		40.54	41.00	40.60				41.06	40.76	40.55
ΔF.S.O.		-.46	0	-.40				+.30	0	-.21
Δ 0		+.71	0	+.55				+.11	0	-.05

Compensation & Bridge
Completion Resistors

Type	1 HB	2 HB
R_1 Ω	5.0K	5.0K
R_2 Ω	500	500
R_3 Ω	500	500
R_4 Ω	5.0K	5.0K
R_{B1} Ω	0	0
R_{B2} Ω	13.2	60
R_{B3} Ω	0	0
R_{B4} Ω	0	0
R_{Z1} Ω	∞	∞
R_{Z2} Ω	22.89K	∞
R_{Z3} Ω	∞	∞
R_{Z4} Ω	1.5K	1.5K
R_S Ω	∞	∞
R_P Ω	4.997	4.998
R_L Ω		

Summarized Performance

Parameter	Goal	1 HB	2 HB
Pressure Range, P.S.I.	450	✓	✓
Overpressure, P.S.I.	900	✓	✓
Excitation, V.D.C.	28	✓	✓
Full Scale Output, mv	120	123.00	122.28
Static Error Band, ± % F.S., B.S.L.	2.0	.11	.24
Temperature Zero Shift Error Band, ± % F.S./100°F	2.0	.29	.07
Temperature Span Shift Error Band, ± % Read./100°F	2.0	.56	.62
Nominal Input Impedance, Ω	5.0K	4.25K	4.25K
Nominal Output Impedance, Ω	900	813	817
Temp. Range-Calibrated, °F	30-130	✓	✓
Temp. Range-Operating, °F	0-150	✓	✓

Konigsberg Instruments, Inc.
2000 East Foothill Blvd., Pasadena, Calif. 91107

Approved:__________ Date:__________

TABLE D-2

NORMAL GAGE DESIGNATIONS FOR MOTOR NO. 1

ASPC Normal Gage Numbers	Konigsberg Instruments
N-1	12
N-2	1
N-3	2
N-4	10
N-5	14
N-6	15
N-7	16
N-8	17
N-9	18
N-10	19
N-11	20
3D	25

TABLE D-3

FULL SCALE MOTOR #1 GAGE CALIBRATIONS

Gage Identification		Temperature					
		30°F		77°F		130°F	
Motor No.	KI No.	mv/psi	Zero Rdg.	mv/psi	Zero Rdg.	mv/psi	Zero Rdg.
S-1	23	2.67	-3.50	2.84	-2.90	3.15	-3.81
S-2	22	2.47	0.30	2.51	0.67	2.65*	3.61
S-3	10	4.13	0.00	4.59	-0.42	5.01	-2.05
S-4	40	3.39	-1.00	4.16	-6.35	3.20	6.93
S-5	18	4.62	-6.50	5.14	-10.79	5.73	-9.90
S-6	17	2.78	1.00	2.82	6.11	2.63	2.35
S-7	15	3.03	4.00	3.01	3.09	3.22	4.08
S-8	41	5.16	1.00	5.71	-4.11	4.92*	-6.80
S-9	16	4.78	-15.00	4.59	-4.10	5.06	-2.23
S-10	12	3.08	14.00	3.20	7.66	3.39	4.50
S-11	24	3.45	16.00	3.87	7.79	4.00	-1.41
S-12	21	3.33	5.50	3.61	1.13	3.32	-1.00
S-13	20	3.18	2.00	3.58	9.04	3.97	9.00
S-14	11	4.28	-0.70	4.70	-3.72	5.34	-4.78
N1-1	450/12	0.274	7.50	0.277	-5.56	0.277	-9.08
N1-2	450/12	0.270	?	0.280	-7.51	0.280	-4.74
N2-1	450/1/5	0.273	-	0.275	1.25	0.276	0.40
N2-2	450/1/5	0.268	-	0.269	-11.67	0.270	-
N3-1	450/2/5	0.269	-1.50	0.272	-5.37	0.274	-11.64
N3-2	450/2/5	0.267	5.80	0.270	5.00	0.270	6.77
N4-1	450/10	0.275	3.00	0.277	-0.76	0.276	4.78
N4-2	450/10	0.274	2.50	0.273	-1.48	0.270	-0.44
N5-1	150/14	0.810	-3.00	0.810	-4.80	0.815	3.52
N5-2	150/14	0.750	-4.00	0.754	-5.85	0.760	-4.65
N6-1	150/15	0.808	-5.50	0.812	-7.50	0.813	0.59
N6-2	150/15	0.805	-1.50	0.806	-3.50	0.810	3.24
N7-1	150/16	0.808	-3.50	0.810	-3.65	0.810	10.11
N7-2	150/16	0.803	2.20	0.806	+0.50	0.808	11.46
N8-1	150/17	0.820	4.0	0.827	2.52	0.830	14.87
N8-2	150/17	0.835	-6.5	0.840	2.50	0.840	-26.72
N9-1	150/18	0.807	3.30	0.810	4.36	0.815	5.20
N9-2	150/18	0.807	-7.00	0.805	-10.52	0.806	-3.72
N10-1	150/19	0.815	-3.00	0.810	-3.42	0.806	3.27
N10-2	150/19	0.825	-5.50	0.820	-7.56	0.825	-1.46
N11-1	150/20	0.825	5.00	0.825	+3.10	0.825	13.54
N11-2	150/20	0.823	-9.00	0.820	-14.43	0.816	-8.76
3DN-1	450/25	0.273	2.00	0.273	-0.19	0.273	-2.38
3DN-2	450/25	0.275	-3.00	0.275	4.33	0.275	0.67

*144°F
110°F

TABLE D-4

SHEAR GAGE CODE FOR MOTOR NO. 1

ASPC Gage Code Shear Gage No.	Konigsberg Gage Code Shear Gage S/N
S-1	23
S-2	22
S-3	10
S-4	40
S-5	13
S-6	17
S-7	15
S-8	41
S-9	16
S-10	12
S-11	24
S-12	21
S-13	20
S-14	11

APPENDIX E

CALIBRATION DATA OF THE STRESS GAGES

USED IN MOTOR NO. 2

CALIBRATION DATA OF THE STRESS GAGES
USED IN MOTOR NO. 2

A. NORMAL STRESS GAGE CALIBRATION DATA

As discussed in Appendix D the normal stress gage, Konigsberg Instruments, Inc. Models P14EB-SD-150 and P143B-SC-450 were calibrated at the rated full scale pressure ranges of 150 and 450 psig respectively at +30, +80, and +130°F. A typical normal stress gage calibration data sheet for Motor No. 2 is shown in Table E-1. The data sheet is for normal gage N6. Tables E-2 and E-3 show the code designations for the normal and shear stress gages used in Motor No. 2. Table E-4 lists the zero readings and the sensitivity of the shear and normal stress gages at the three temperatures previously mentioned.

B. SHEAR STRESS GAGE CALIBRATION DATA

The shear gages used in Motor No. 2 were fabricated by Konigsberg Instruments, Inc. and were calibrated by ASPC and HL&A. Figures E-1 and E-2 show the constant shear rate calibration for shear gages S-2 and S-3 (SN 26 and 27) in the inverted and upright positions at 33, 77, and 130°F. Figures E-3 and E-4 show the calibration curves for the same shear gages during the normal response and superimposed hydrostatic calibration tests at 77 ± 3°F.

The balance of the calibration data and curves for the shear and normal stress gages are in the document files.

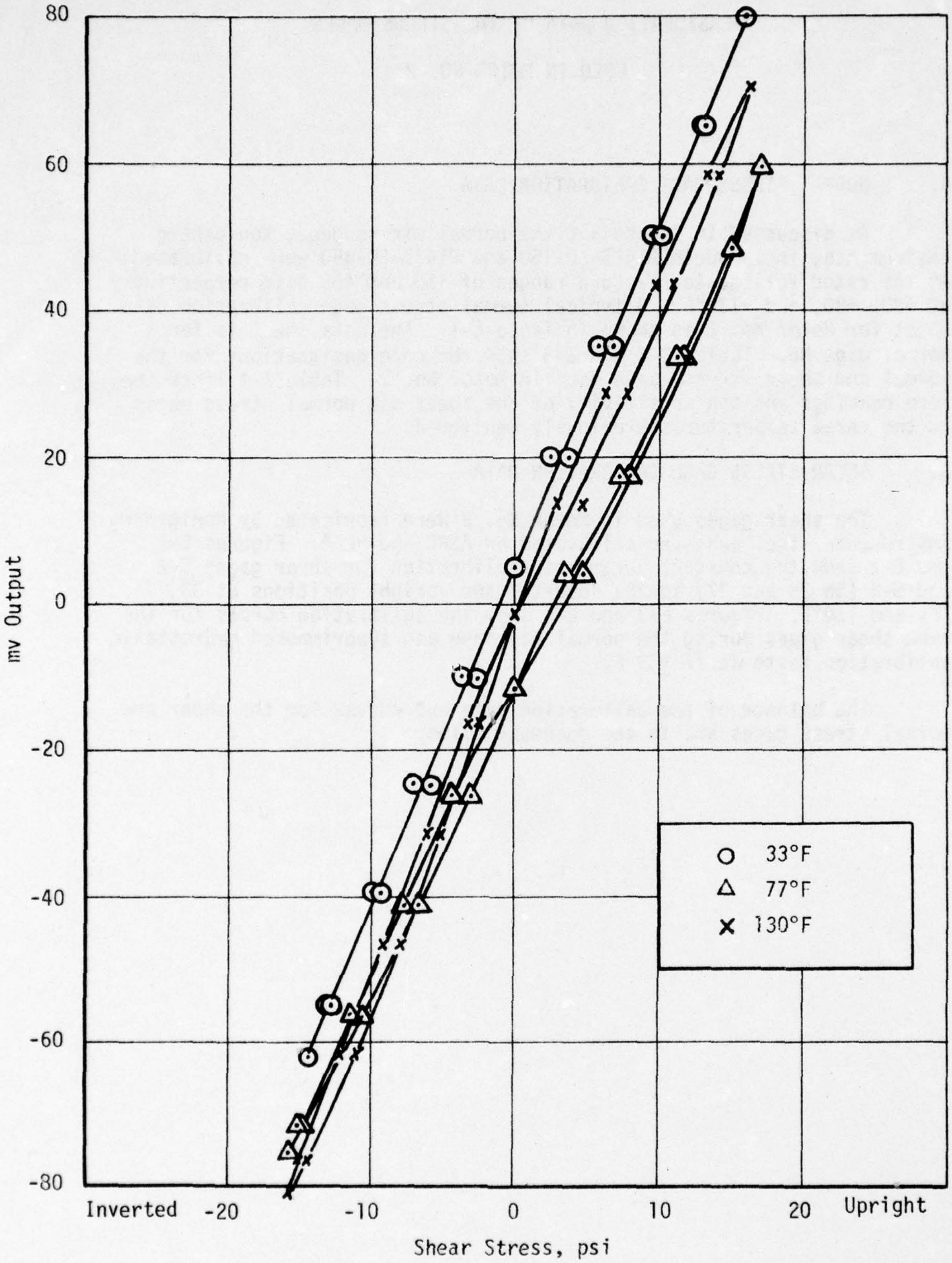


FIGURE E-1. SHEAR CALIBRATION OF GAGE NO. 26
MOTOR NO. 2, SH2

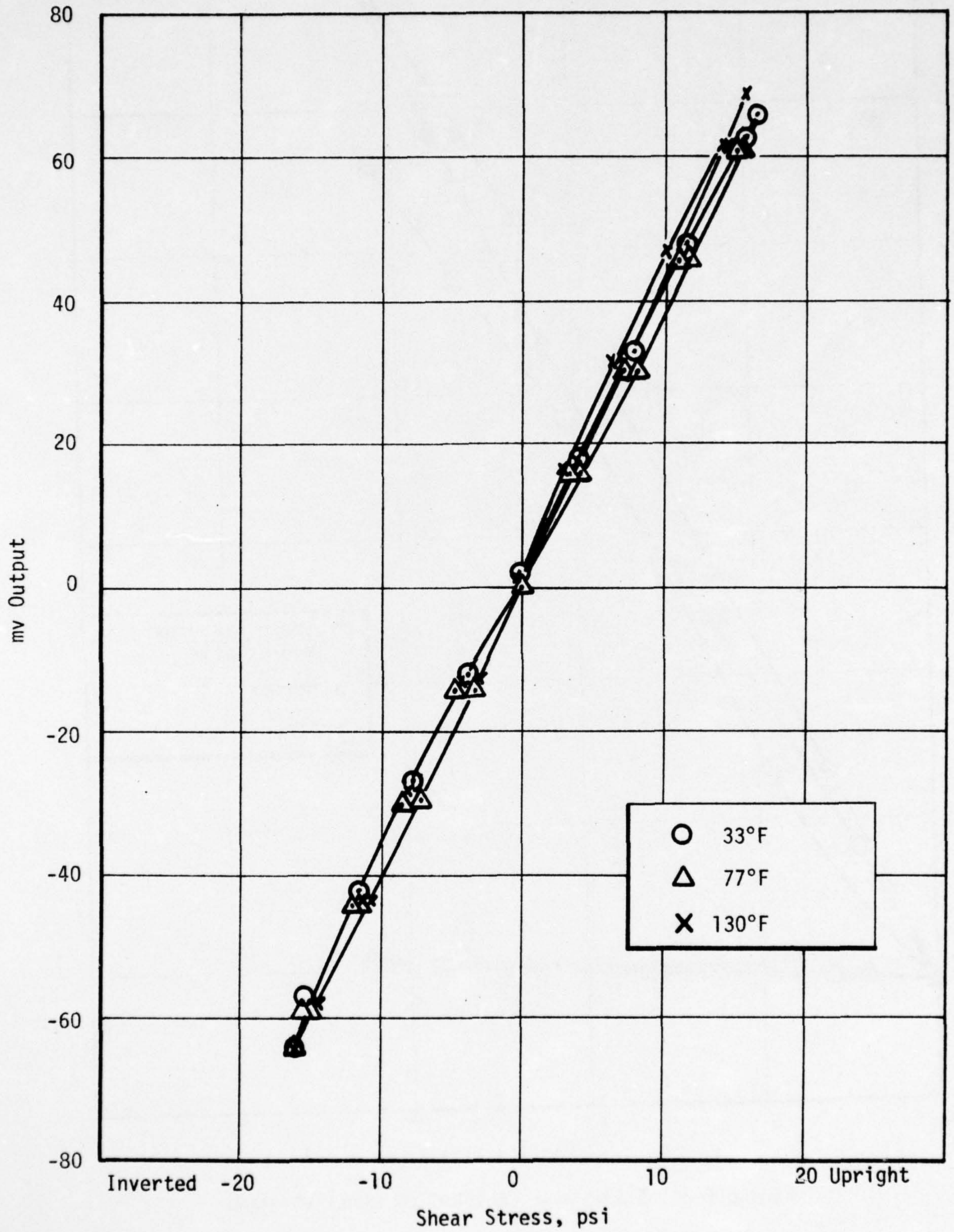


FIGURE E-2. SHEAR CALIBRATION OF GAGE NO. 27
MOTOR NO. 2, SH3

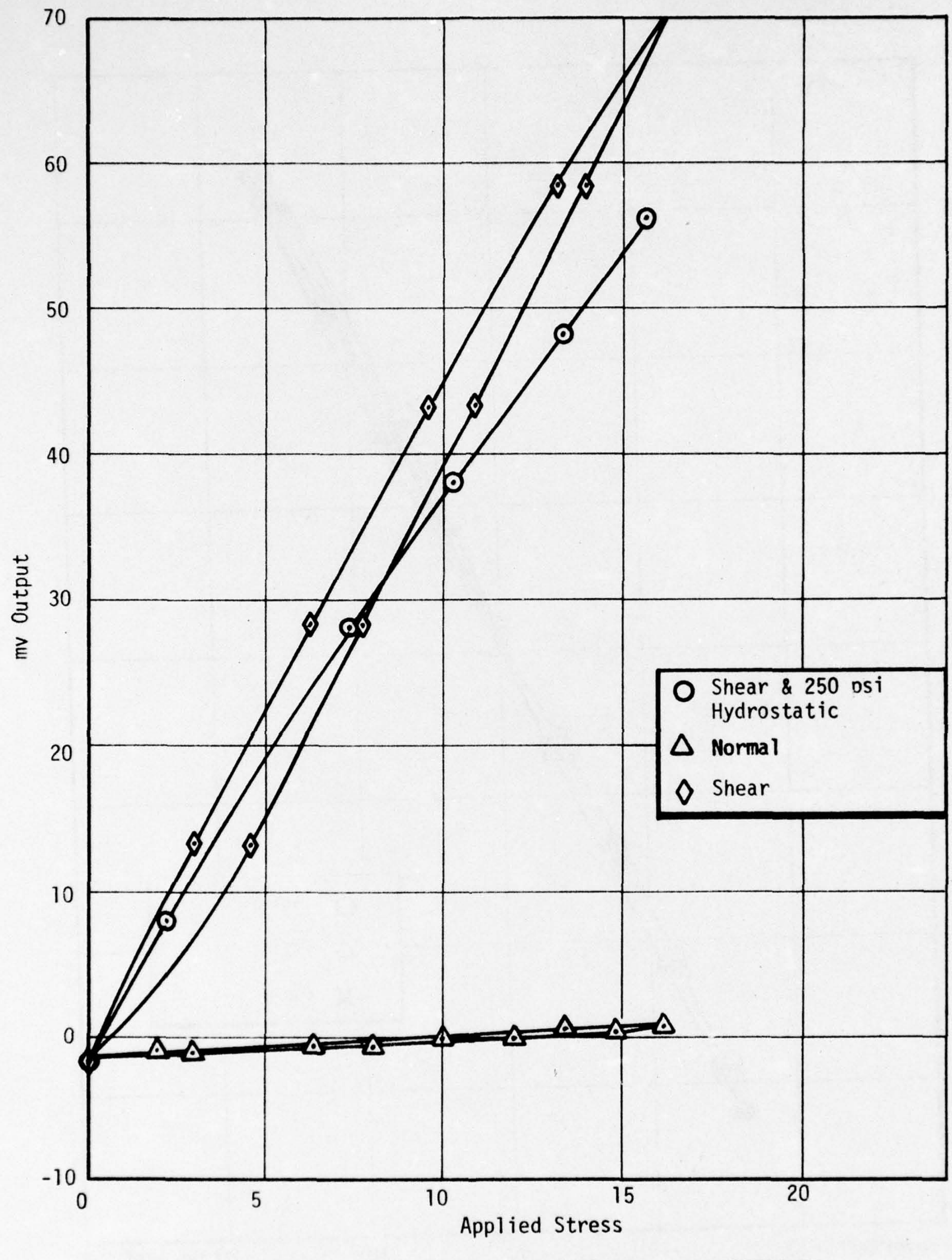


FIGURE E-3. SHEAR GAGE CALIBRATION UNDER PRESSURE

AND NORMAL STRESS RESPONSE; GAGE NO. 26
MOTOR NO. 2, SH2

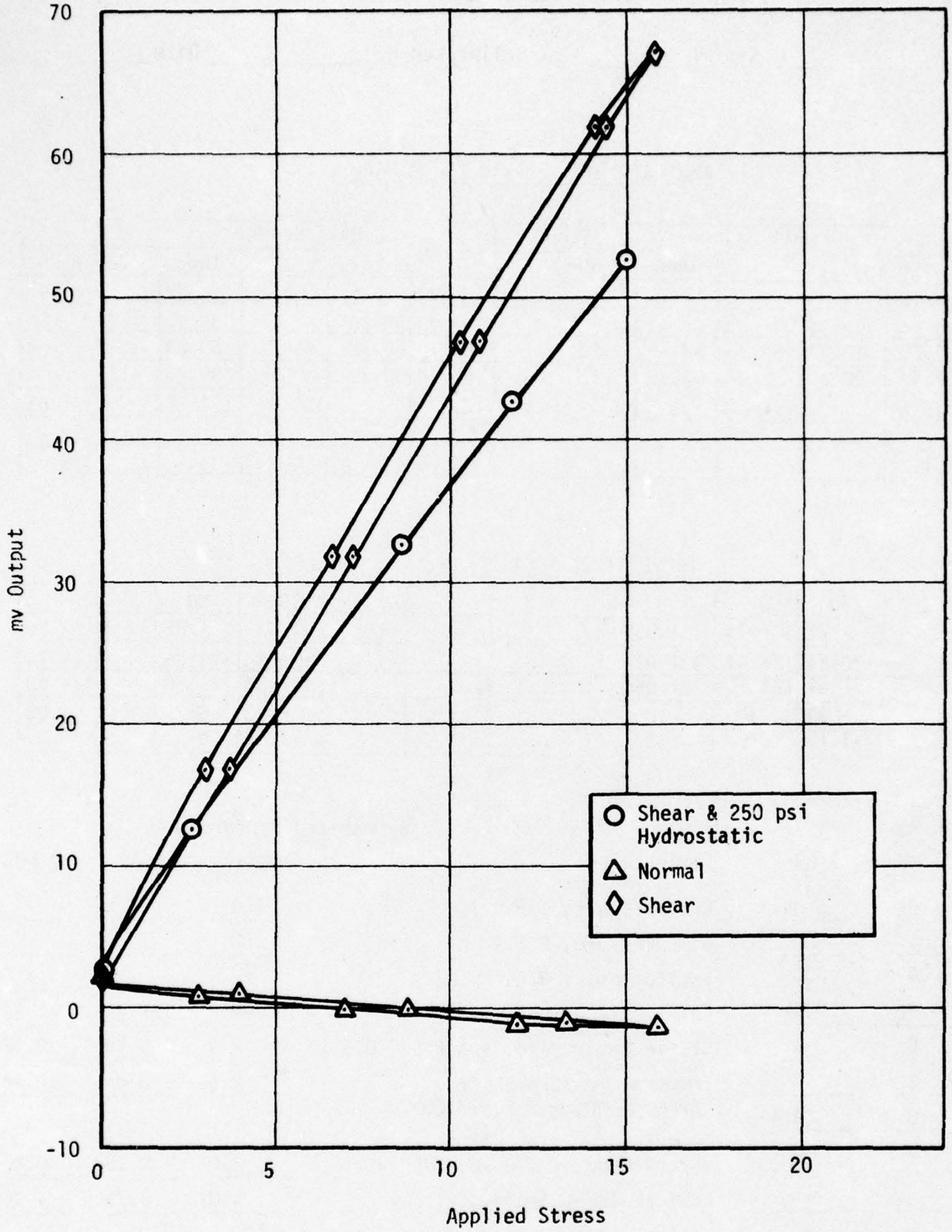


FIGURE E-4. SHEAR GAGE CALIBRATION UNDER PRESSURE AND NORMAL STRESS RESPONSE; GAGE NO. 27
MOTOR NO. 2, SH2

TABLE E-1
VENDOR OBSERVATIONS OF GAGE CALIBRATIONS

Model______________ Serial__________ Calibrated By___________ Date____________

AMBIENT TEMP. STATIC ERROR BAND

PSI	1 Half Bridge					2 Half Bridge				
	Eo (mv)			Theo.	Dev'n.	Eo (mv)			Theo.	Dev'n
0	-.16	-.03	↓	-.16	+.13	-.30	-.26	↓	-.30	+.04
375	29.84	29.94	-	30.14	-.30	29.90	30.00	-	30.12	-.22
75	60.22	60.29	60.28	60.45	-.23	60.38	60.38	60.36	60.53	-.17
112.5	90.57	90.66	-	90.75	-.18	90.70	90.78	-	90.95	-.25
	121.05		121.08	121.05	-.03	121.36		121.39	121.36	+.03
		↑					↑			
F.S.O.	121.21				Σ .43	121.66				Σ .29

TEMPERATURE TEST DATA

PSI °F		30	80	130				30	80	130
0		-.77	+.33	+.03				-1.03	+.05	-.54
150		120.84	121.44	121.09				120.80	121.65	121.14
F.S.O.		121.61	121.11	121.06				121.83	121.60	121.68
ΔF.S.O.		+.50	0	-.05				+.23	0	+.08
Δ 0		-1.10	0	-.30				-1.08	0	-.59

Compensation & Bridge
Completion Resistors

Type	1 HB	2 HB
R_1 Ω	5.0K	5.0K
R_2 Ω	500	500
R_3 Ω	500	500
R_4 Ω	5.0K	5.0K
R_{B1} Ω	0	0
R_{B2} Ω	0	0
R_{B3} Ω	10.3	9.4
R_{B4} Ω	0	0
R_{Z1} Ω	∞	∞
R_{Z2} Ω	∞	∞
R_{Z3} Ω	55.0K	30.0K
R_{Z4} Ω	∞	∞
R_S Ω	2.0K	2.2K
R_P Ω	∞	∞
R_L Ω	5.0K	5.0K

Summarized Performance

Parameter	Goal	1 HB	2 HB
Pressure Range, P.S.I.	150	✓	✓
Overpressure, P.S.I.	300	✓	✓
Excitation, V.D.C.	28	✓	✓
Full Scale Output, mv	120	121.21	121.66
Static Error Band, ± % F.S., B.S.L.	2.0	0.18	0.12
Temperature Zero Shift Error Band, ± % F.S./100°F	2.0	0.45	0.44
Temperature Span Shift Error Band, ± % Read./100°F	2.0	0.23	0.13
Nominal Input Impedance, Ω	5.0K	4.75K	4.95K
Nominal Output Impedance, Ω	900	770	770
Temp. Range-Calibrated, °F	30-130	✓	✓
Temp. Range-Operating, °F	0-150	✓	✓

Konigsberg Instruments, Inc.
2000 East Foothill Blvd., Pasadena, Calif. 91107

Approved:____________________ Date:____________

TABLE E-2

NORMAL GAGE DESIGNATIONS FOR

MOTOR NO. 2

ASPC Normal Gage Nos.	Konigsberg Instruments S/N
1	3
2	11
3	4
4	22
5	21
6	6
7	29
8	3
9	28
10	7
11	4
26	26
27	27

TABLE E-3

SHEAR GAGE CODE FOR MOTOR NO. 2

ASPC Gage Code Shear Gage No.	Konigsberg Gage Code Shear Gage S/N
S-1	30
S-2	26
S-3	27
S-4	42
S-5	32
S-6	29
S-7	31
S-8	33
S-9	S-B
S-10	34
S-11	13
S-12	35
S-13	25
S-14	36
A	S-A
B	S-C
C	S-D

TABLE E-4

FULL SCALE MOTOR NO. 2 GAGE DATA

Gage Identification		Temperature					
		33°F	30°F	80°F	74°F	130°F	110°F
Motor No.	KI or HL&A No.	Sensitivity mv/psi	Zero Reading	Sensi-tivity mv/psi	Zero Reading	Sensi-tivity mv/psi	Zero Reading
S-1	30	4.35	+2.1 mv	4.6	+1.8	4.8	+2.7
S-2	26	4.0	-7.3	4.8	+1.8	4.6	+6.7
S-3	27	3.8	-1.4	4.1	-1.8	3.8 (144°F)	-2.0
S-4	42	3.05	-3.2	3.65	+4.5	3.7	+11.1
S-5	32	3.6	+0.2	3.6	+3.5	3.5	+5.2
S-6	29	3.6	+8.3	3.85	+1.3	3.75	-4.3
S-7	31	4.0	-6.5	3.9	0.0	3.75 (144°F	-1.2
S-8	33	2.0	+10.0	2.0	+6.5	2.0	+4.5
S-9	S-B	*	-0.5	*	0.0	* (144°F)	-1.8
S-10	34	2.6	+42.0	2.4	+37.5	2.2	+35.0
S-11	13	3.2	+5.8	3.0	-0.5	3.5 (144°F)	-3.5
S-12	35	2.6	+4.0	2.3	+1.2	2.45	+1.4
S-13	25	2.8	-2.4	3.1	-2.6	3.2	-1.7
S-14	36	2.1	-0.7	1.9	-1.0	1.6	-1.8
Shear A	S-A	*	-3.7	*	-1.5	*	+0.4
Shear C	S-C	*	+0.2	*	0.0	*	-1.0
Shear D	S-D	*	+0.1	*	-1.0	*	-0.3
N1-1	450/3-1	.268	-19.2	.269	-19.2	.271	-20.2
N1-2	450/3-2	.271		.272		.272	
N2-1	450/11-1	.269	-12.0	.271	-8.6	.269	-7.2
N2-2	450/11-2	.272	-14.9	.274	-14.8	.272	-15.3
N3-1	450/4-1	.275	-10.2	.274	-4.0	.272	-4.3
N3-2	450/4-2	.273	-10.3	.273	-9.0	.274	-11.2

* Viscoelastic calibration. See curves.

TABLE E-4 (CONT.)

FULL SCALE MOTOR NO. 2 GAGE DATA

Gage Identification		Temperature					
		33°F	30°F	80°F	74°F	130°F	110°F
Motor No.	KI or HL&A No.	Sensitivity mv/psi	Zero Reading	Sensitivity mv/psi	Zero Reading	Sensitivity mv/psi	Zero Reading
N4-1	450/22-1	.270	-3.0	.270	-2.5	.270	-1.3
N4-2	450/22-2	.272	-2.1	.272	-1.6	.274	-0.3
N5-1	150/21-1	.823	-7.5	.821	-8.4	.818	-8.6
N5-2	150/21-2	.820	-18.4	.821	-17.7	.826	-17.8
N6-1	150/6-1	.811	+2.0	.807	+1.7	.807	+0.9
N6-2	150/6-2	.812	+5.9	.811	+5.1	.811	+3.4
N7-1	150/29-1	.816	+3.7	.814	+3.2	.816	+4.0
N7-2	150/29-2	.820	-5.1	.816	-4.3	.818	-3.8
N8-1	150/3-1	.825	+18.7	.819	+18.5	.813	+17.3
N8-2	150/3-2	.818	+20.3	.818	+21.0	.812	+20.7
N9-1	150/28-1	.811	-8.0	.813	-10.5	.811	-11.5
N9-2	150/28-2	.801	-9.5	.806	-10.7	.807	-11.2
N10-1	450/7-1	.270	+18.0	.271	+16.7	.268	+18.0
N10-2	450/7-2	.272	+20.0	.271	+18.7	.274	+20.5
N11-1	150/4-1	.841	+16.8	.839	+15.2	.841	+14.8
N11-2	150/4-2	.806 (-75)	+15.3	.806	+15.5	.805 (+180)	+15.2
N26-1	450/26-1	.268 (-75)	-10.9	.269	-8.0	.270 (+180)	-6.3
N26-2	450/26-2	.270 (-75)	-10.7	.270	-7.5	.270 (+180)	-6.3
N27-1	450/27-1	.270 (-75)	-0.7	.266	+2.8	.267 (+180)	+4.3
N27-2	450/27-2	.268	+2.6	.266	-1.7	.270	-1.8
BI-7SH	3D5	*	+13.0		+10.1		+7.6
BI-5SH	3D5	*	+7.0		+20.7		+25.7
6A-D	3D5	*	-12.2		+11.0		+23.0

* Viscoelastic calibration. See curves.

TABLE E-4 (CONT.)

FULL SCALE MOTOR NO. 2 GAGE DATA

Gage Identification		Temperature					
		33°F	30°F	80°F	74°F	130°F	110°F
Motor No.	KI or HL&A No.	Sensitivity mv/psi	Zero Reading	Sensitivity mv/psi	Zero Reading	Sensitivity mv/psi	Zero Reading
6B-D	3D5	*	+5.1		+18.7		+25.0
5A-D	3D5	*	+23.8		+28.7		+30.6
7A-D	3D5	*	-3.8		+0.4		+1.6
2+	3D6-4	*	+7.0		-1.8		-11.8
2-	3D6-3	*	-10.3		-20.5		-13.0
3+	3D6-6	*	-9.0		-19.0		-29.0
3-	3D6-5	*	-13.8		-27.6		-37.5
1+	3D6-2	*	-13.5		-18.0		-24.5
1-	3D6-1	*	+16.3		+11.3		+3.0
		(0°F)				(150°F)	
N35	150/35-1	.761		.759		.762	
		(0°F)				(150°F)	
N36	150/36-1	.792		.804		.812	

* Viscoelastic calibration. See curves.

APPENDIX F

ELECTRICAL SYSTEM, TRANSDUCER

CIRCUITS AND BRIDGE COMPLETION UNIT

(Motor Nos. 1 and 2, except when noted)

ELECTRICAL SYSTEM, TRANSDUCER CIRCUITS, & BRIDGE COMPLETION UNIT

A. ELECTRICAL SYSTEM

The total electrical system used to instrument and to monitor the grain stresses, strain, and temperatures for the Flex Case/Grain Interaction Program consists of the transducers, the interconnecting network, the bridge completion unit, and the recording system (Figure F-1). The transducer system includes the normal gages, shear gages, thermocouples, event gages, clip gages, and L.V.D.T.'S. The interconnection network is made up of the connecting wires between the gages and the bridge completion unit with their terminations and the interconnection cables from the bridge completion unit to the switching and terminating network in the trailer to the recording system. The bridge completion system consists of four aluminum junction boxes, mounted directly onto the motor skirt, which contains the half-bridge completion networks (printed circuit boards) for the shear and the normal gages. It also contains the necessary terminations and feedthroughs for the event gages and thermocouples. The recording system consists of a 25 channel scanner/programmer, power supplies, temperature strip chart recorder, digital recorder/printer, an integrating digital voltmeter, auxiliary measuring equipment, oscillograph, and alternate strip charts and power supply. A pictorial view for a typical stress gage connected to the B.C.U. is shown in Figure F-2.

B. TRANSDUCER CIRCUITS

The electrical circuits of a typical normal stress and shear stress gage are shown in Figure F-3. As previously mentioned, a typical stress gage consists of two 500 ohm semiconductor strain gages arranged into a half-bridge configuration. Three wires exit from the stress gage. Figure F-4 shows the normal gage, model P14EB-SC-150, connected to its bridge completion unit. When the B.C.U. is connected, a typical wheatstone bridge is balanced by artificially introducing balancing resistors, RB's, in the bridge. The full-scale ranging and temperature connections are accomplished by means of adjusting the R_L and R_Z resistors at various temperatures. Resistors R_1 and R_4 are the 5K ohm bridge completion resistors. The resistor R_S is generally 2K to 5K ohms, and is used to limit the current to the bridge and to provide constant current to the bridge to maintain linearity of the semi-conductor bridge.

Resistors R_2 and R_3 are the 500 ohm semi-conductor strain gages of the normal stress gage. The input is 28 volts D.C., and the full-scale output is generally 125 mv for the 150 psi and the 450 psi normal gages. A brief analysis of this circuit (Figure F-5), assuming R_s = 2000 ohms, showed that the input current is approximately 5.1 ma. The dropping resistor (R_s) has a voltage drop of 12.0 volts. Therefore, the voltage across the gage is approximately 1.50 volts. The heat dissipated from each gage is approximately 3 milliwatts.

The typical circuit of the shear stress gage, model H2A, connected to the B.C.U. is shown in Figure F-6. The equivalent circuit for the shear gage is a simplified version of the wheatsone bridge as compared with the normal stress gage. The strain gage circuit only consists of the 5K ohms bridge completion resistors, the two dropping resistors (two - 5K ohms) and the two semi-conductor strain gages, 500 ohms each, in the shear gage.

The voltage and current parameters of the shear stress gage are presented in Figure F-7.

The electrical circuit for a clip gage and a 3D gage are shown in Figures F-8 and F-9. The clip gage includes 4 active semi-conductor strain gages. The 3D gage circuit includes 6 semi-conductor gages connected into a common half-bridge. The electrical circuit for an LVDT is shown in Figure F-10.

C. BRIDGE COMPLETION UNIT

The B.C.U. consists of four junction boxes used to house all termination points from the stress gages and their bridge completion circuits (printed circuit boards).

The junction boxes used were purchased from Zero Mfg. Co. (Part No. Z120-192-64EE). It is a rectangular aluminum box with a separate moisture seal cover. Terminal strips were mounted in place to accept the input leads from the gages and the interconnections from the printed circuit board of the bridge completion network. All the output leads are fastened onto separate terminal strips. The identification of terminals and interconnections of the four J boxes with the respective stress gages are shown in Figures F-11 to F-14 for Motor No. 1. They show the interconnection for the 0°, 90°, 180° and 270° junction boxes, respectively. The assignment of gages to respective boxes are shown in Table F-1. Identification of terminals and interconnections of the four J boxes of Motor No. 2 are given in the documentary file.

Printed circuit boards were designed and fabricated to accommodate the required completion bridge network for the gages. The primary objectives were to standardize bridge completion connections, to minimize wiring errors, and to minimize poor solder joints. The printed circuit board layout to scale is given in Volume I (Figure 38). Due to various loading conditions, it was designed to be permanently horizontally mounted and was purposely designed to eliminate the usual type of printed circuit board connections with a socket for connections because of its tendencies to work loose under stringent loading conditions.

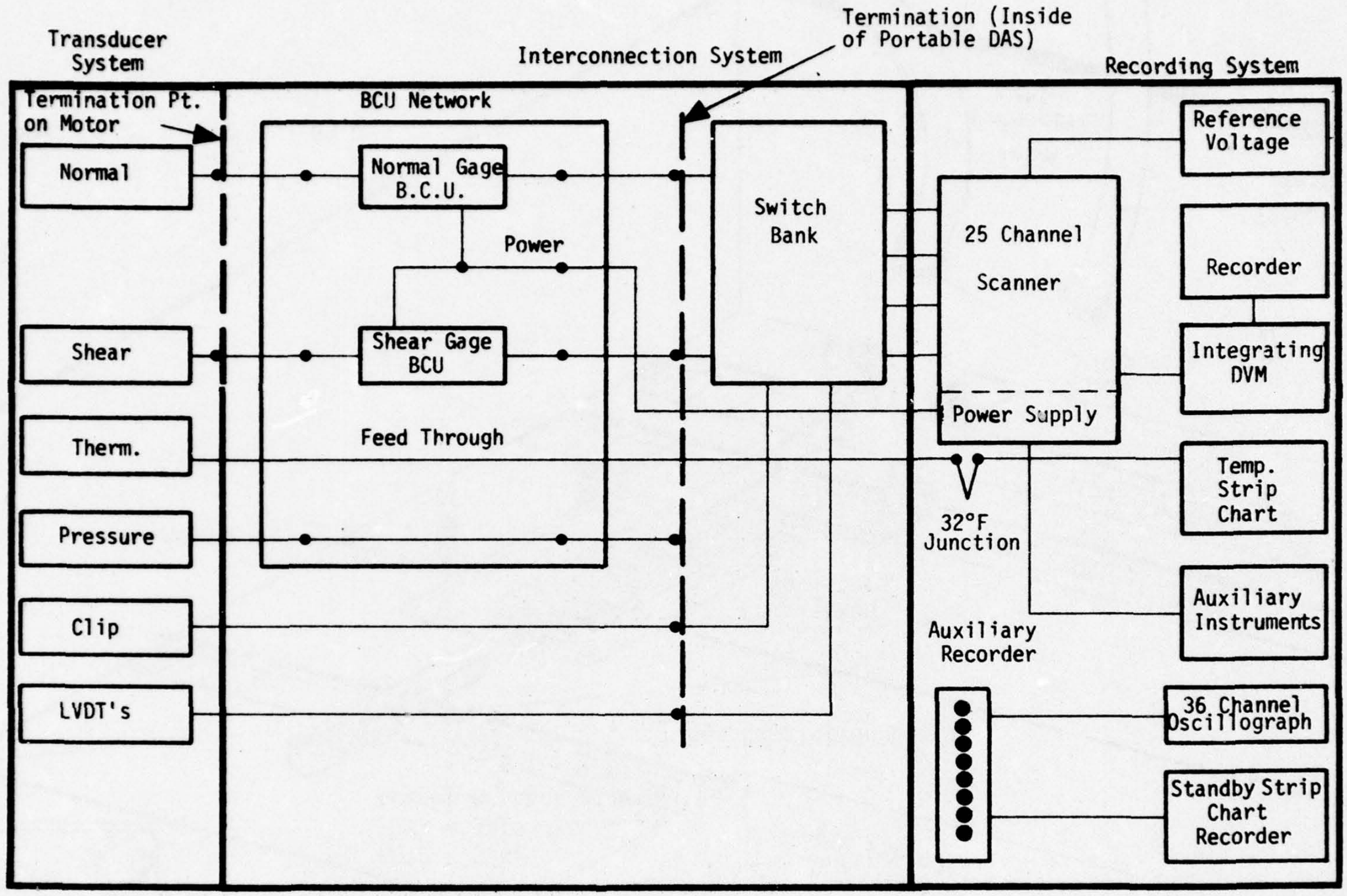


FIGURE F-1. TOTAL ELECTRICAL SYSTEM FOR FLEX CASE INSTRUMENTATION

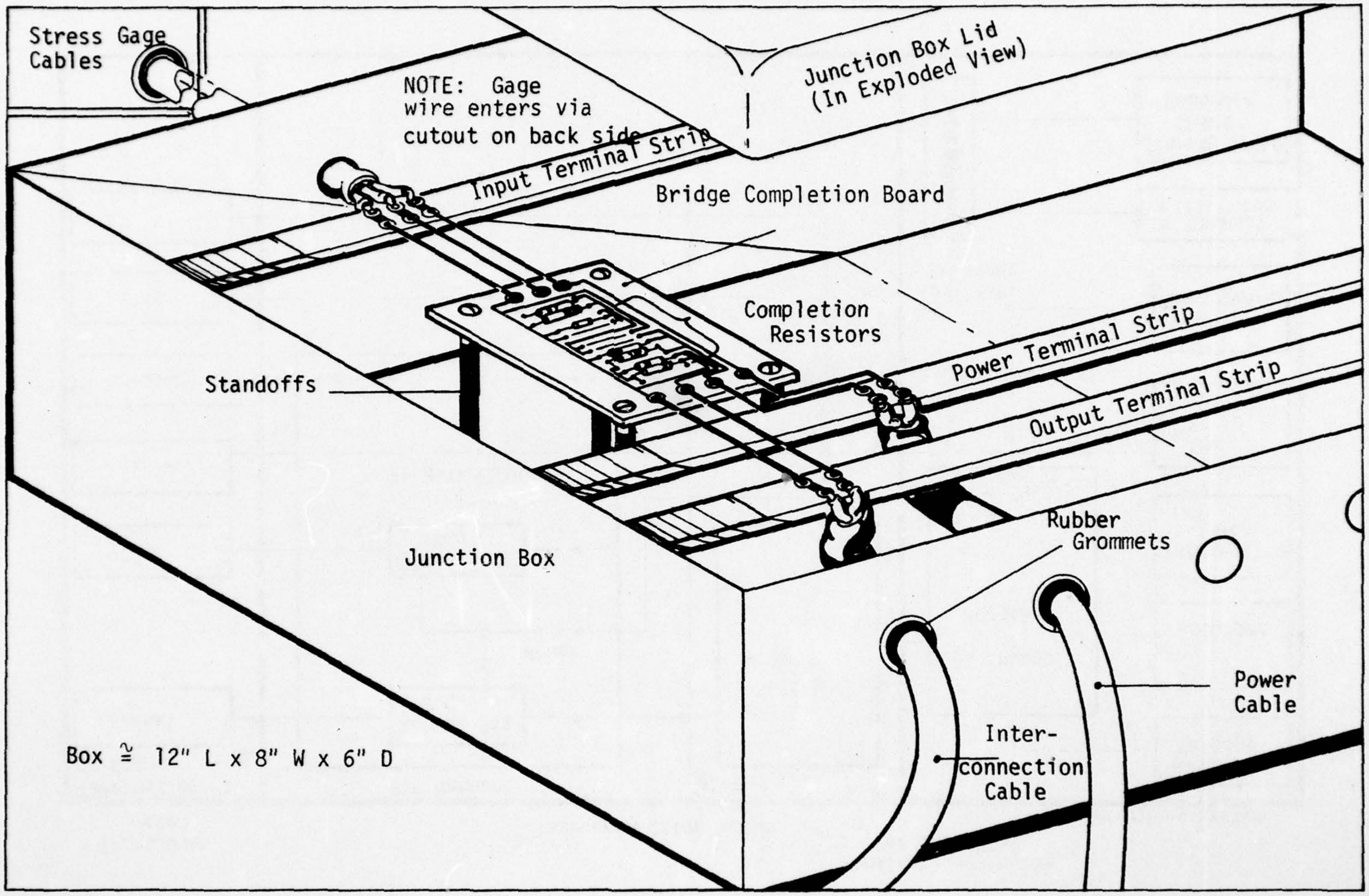
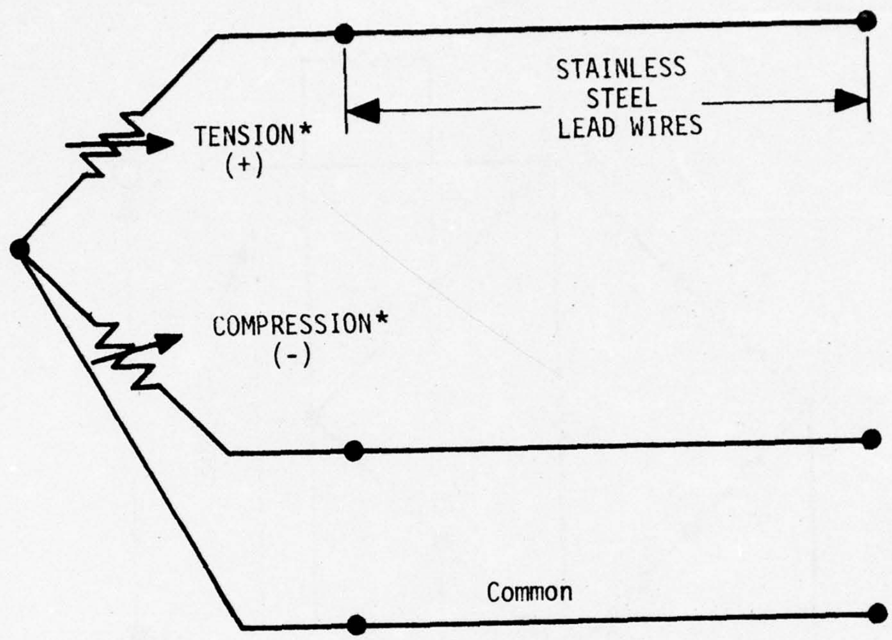


FIGURE F-2. TYPICAL STRESS GAGE CONNECTION TO B.C.U.



* Two - 500 Ω semi-conductor gages.

FIGURE F-3. SCHEMATIC OF TYPICAL SHEAR AND NORMAL STRESS GAGES

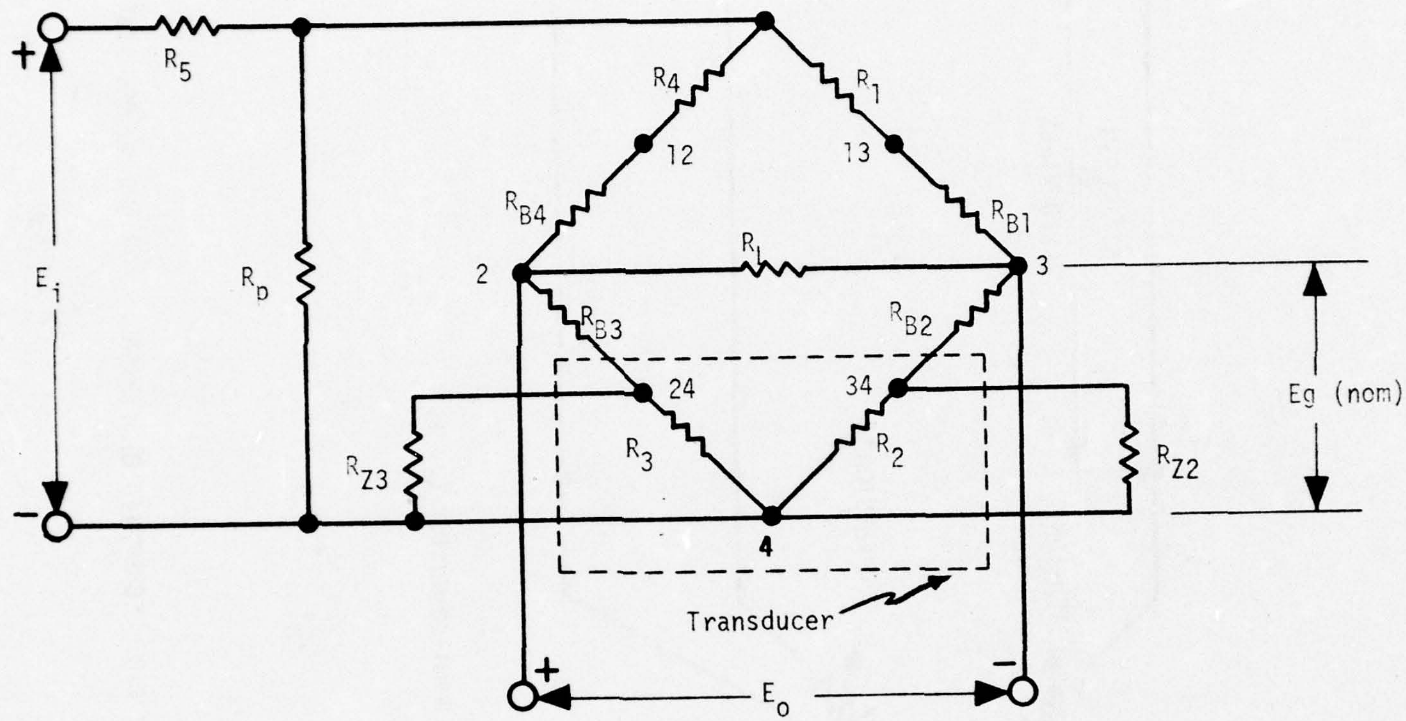


FIGURE F-4. SCHEMATIC OF A TYPICAL NORMAL STRESS GAGE

CONNECTED TO THE B.C.U.

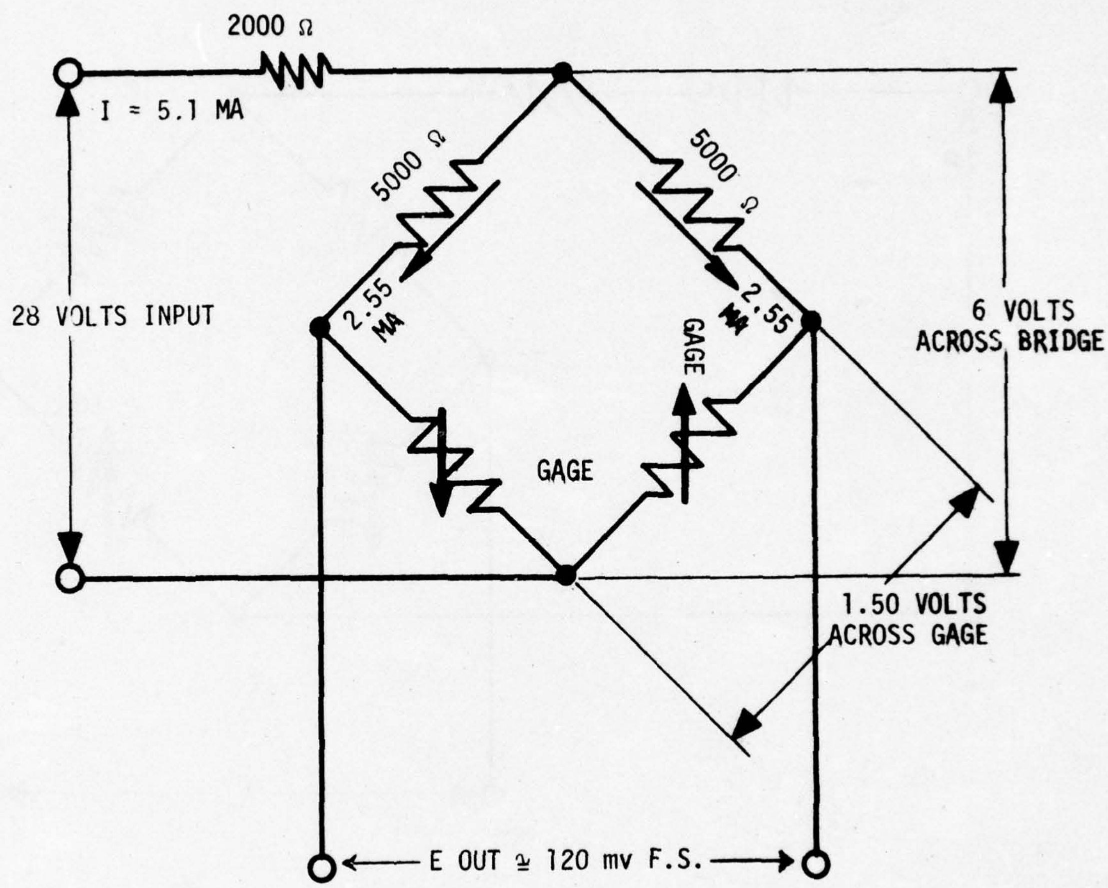


FIGURE F-5. CIRCUIT ANALYSIS OF A TYPICAL NORMAL STRESS GAGE

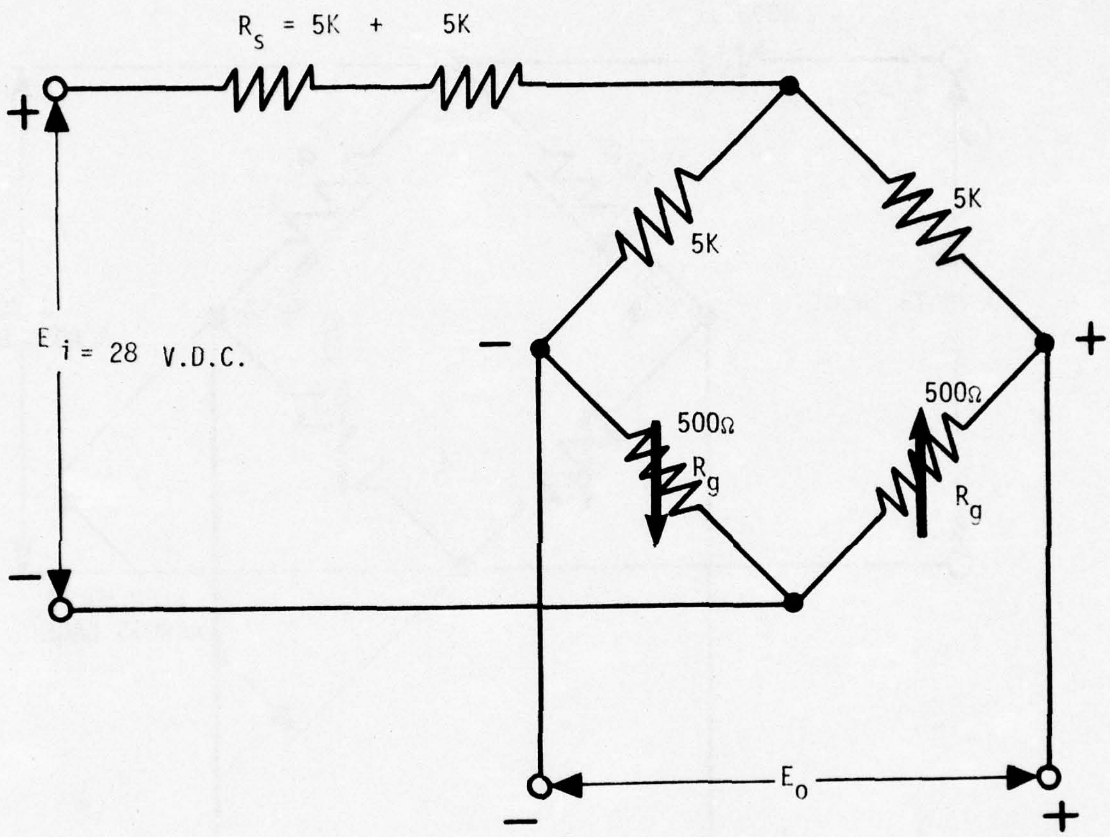


FIGURE F-6. SCHEMATIC OF A TYPICAL SHEAR GAGE CONNECTED TO THE B.C.U.

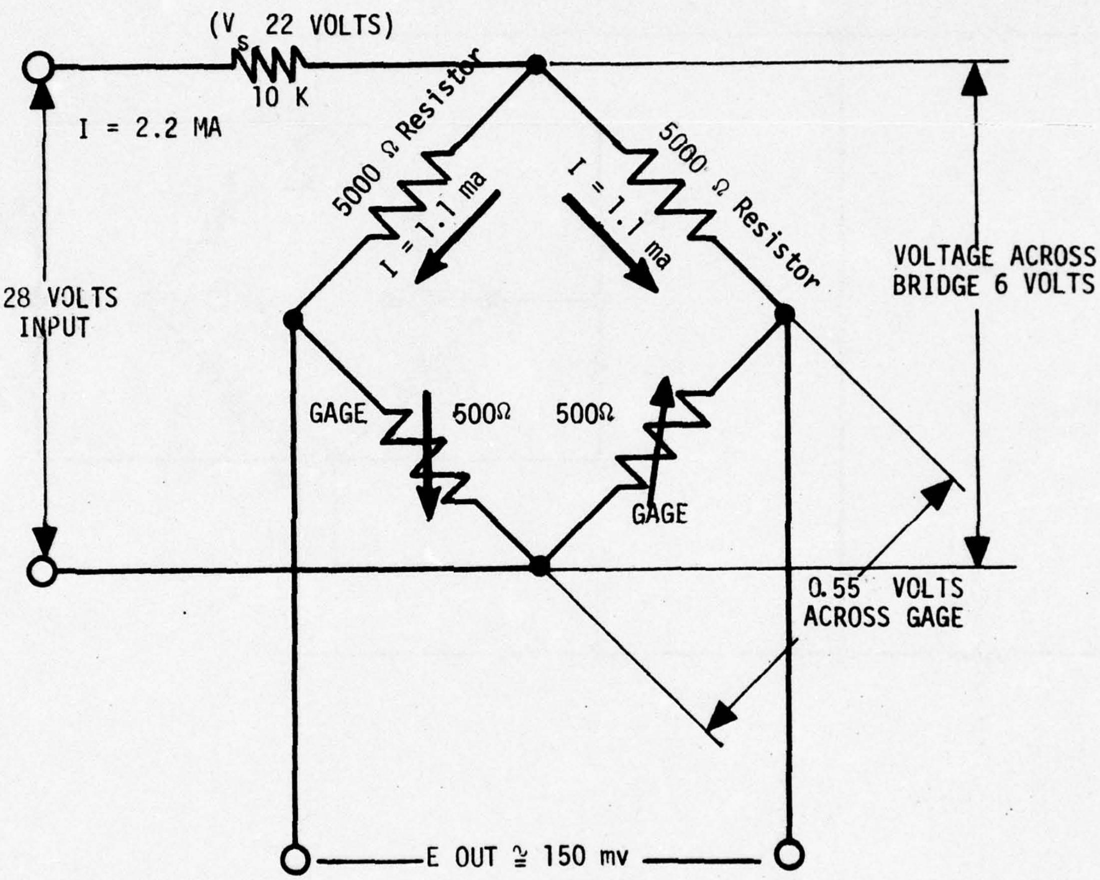


FIGURE F-7. CIRCUIT ANALYSIS OF A TYPICAL SHEAR GAGE

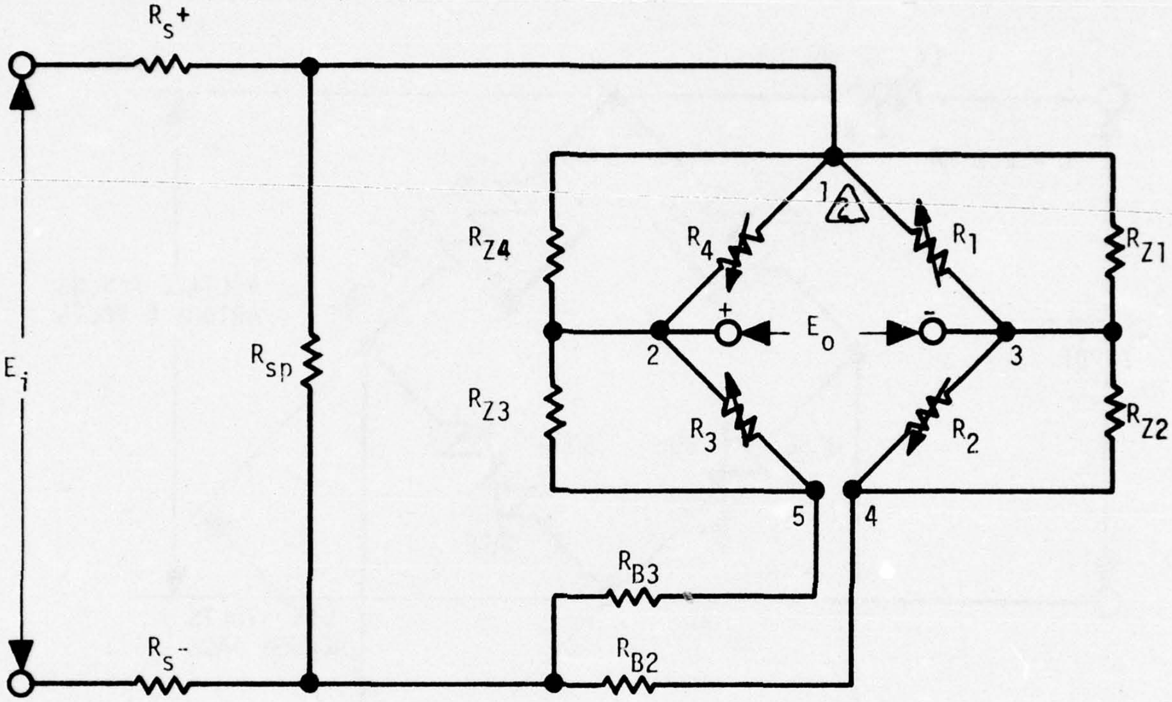
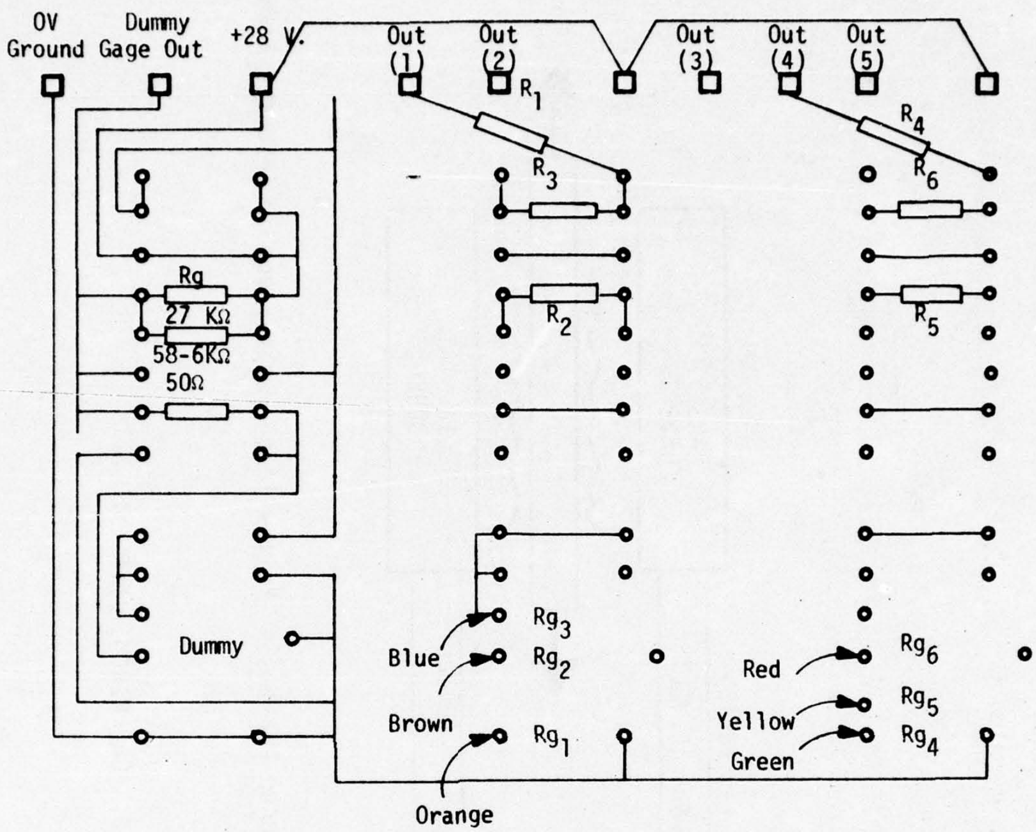
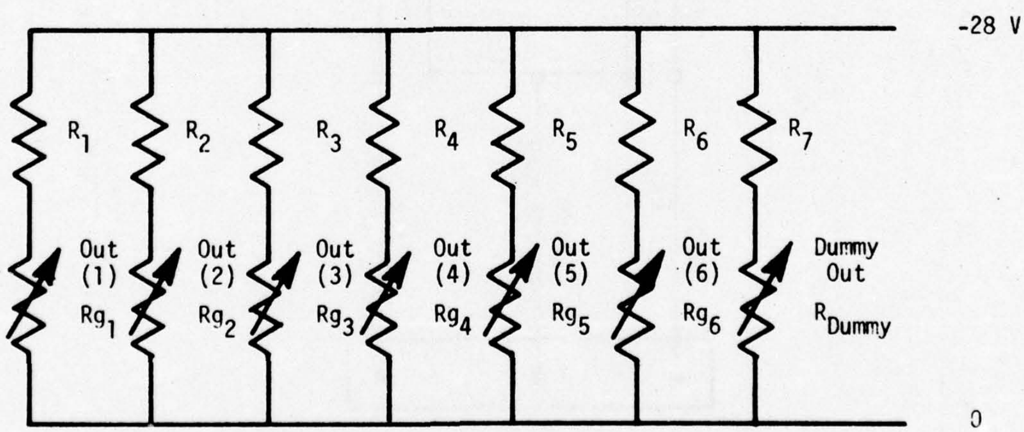


FIGURE F-8. SCHEMATIC OF KONIGSBERG INSTRUMENTS MODEL J1C CLIP GAGE

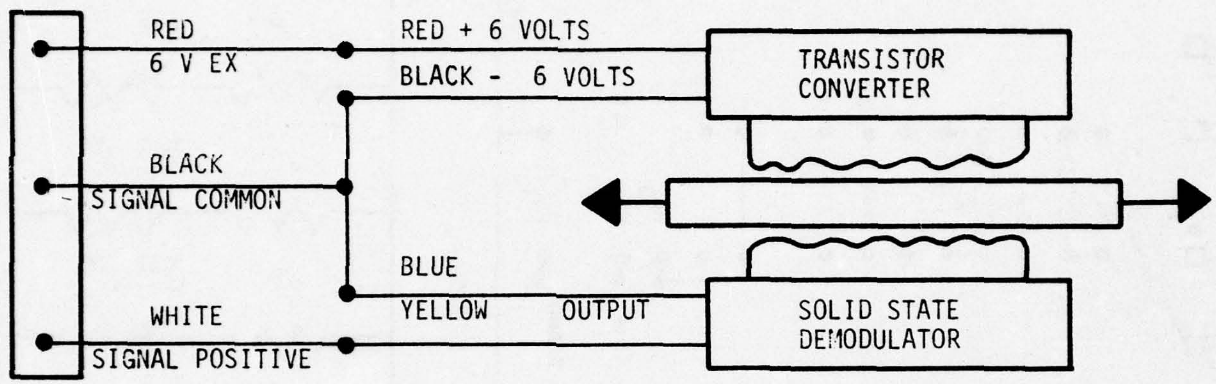
3D Gage Employs Three Gage Circuit Boards





To measure gage outputs: Use Dummy Out as common - dc line and measure to Out(1), Out(2), etc.

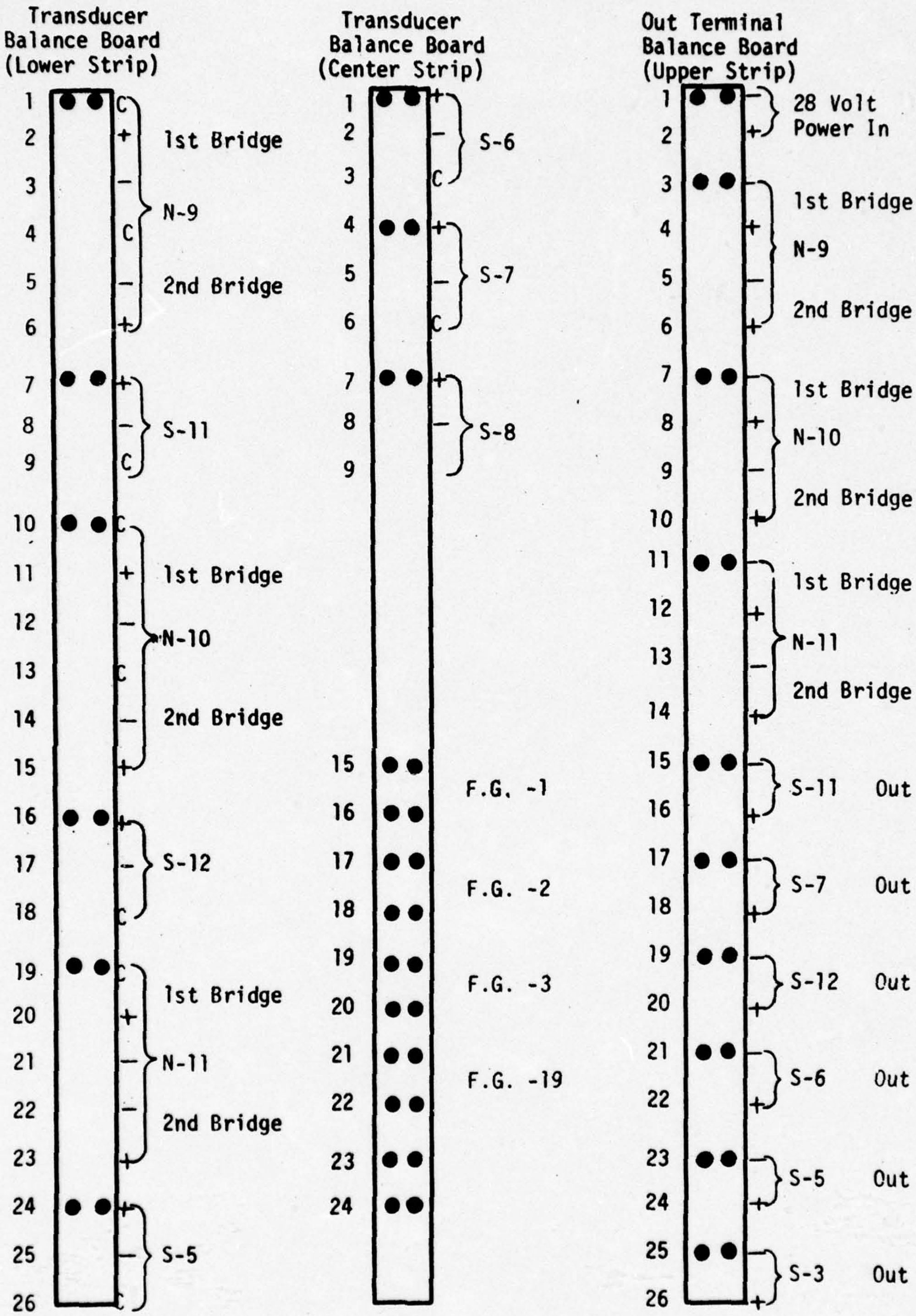
FIGURE F-9. SCHEMATIC OF THE 3D GAGE



STANDARD PHASING: Yellow lead + when probe is inserted toward leads.

FIGURE F-10. ELECTRICAL CIRCUIT FOR AN LVDT

0° Terminal Motor No. 1



NOTE: Thermocouples Nos. 5, 6, 7, ,7 & 18 pass through this junction box; not connected to terminal strip.

FIGURE F-11. TERMINAL IDENTIFICATION FOR 0° JUNCTION BOX

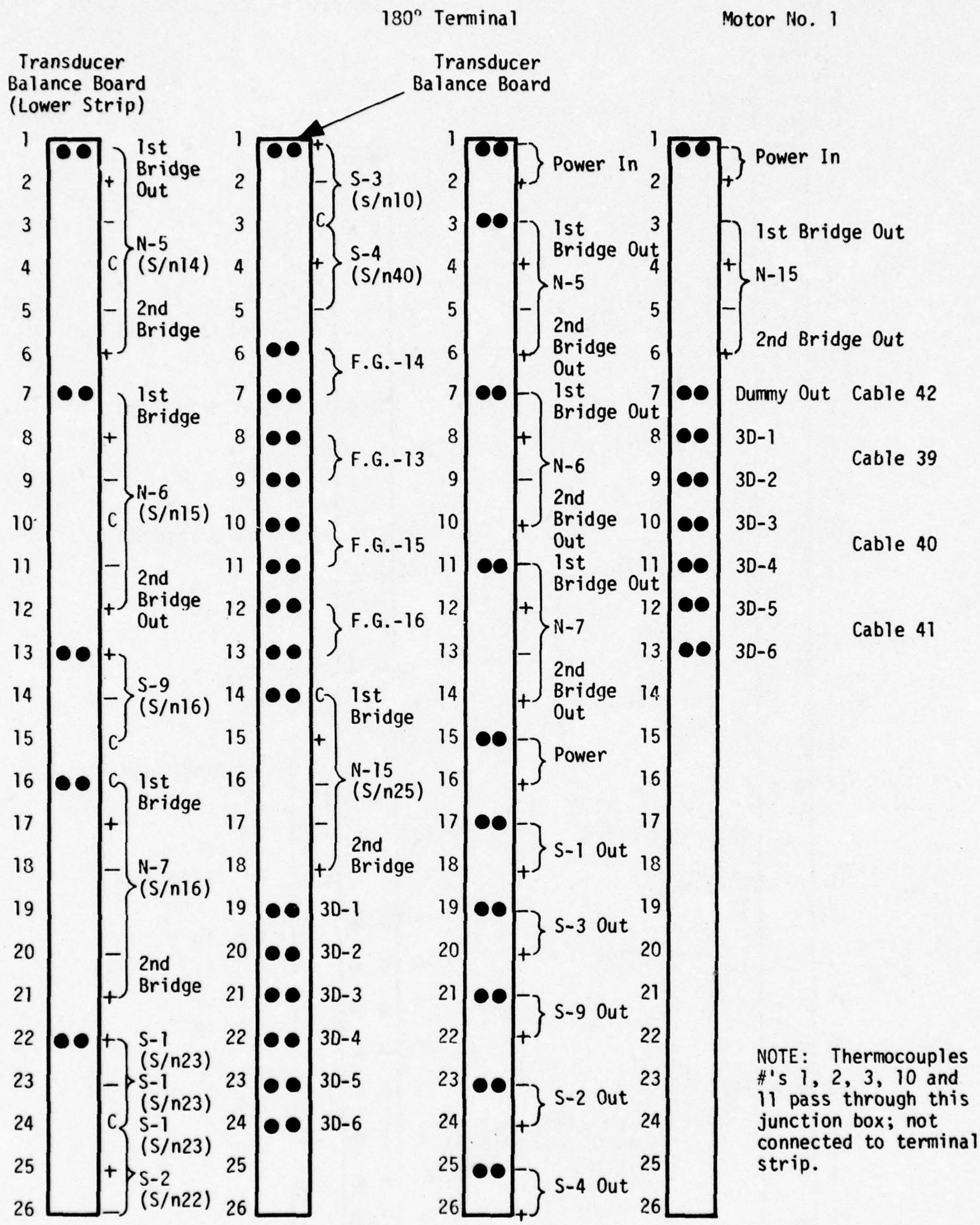


FIGURE F-13. TERMINAL IDENTIFICATION FOR 180° JUNCTION BOX

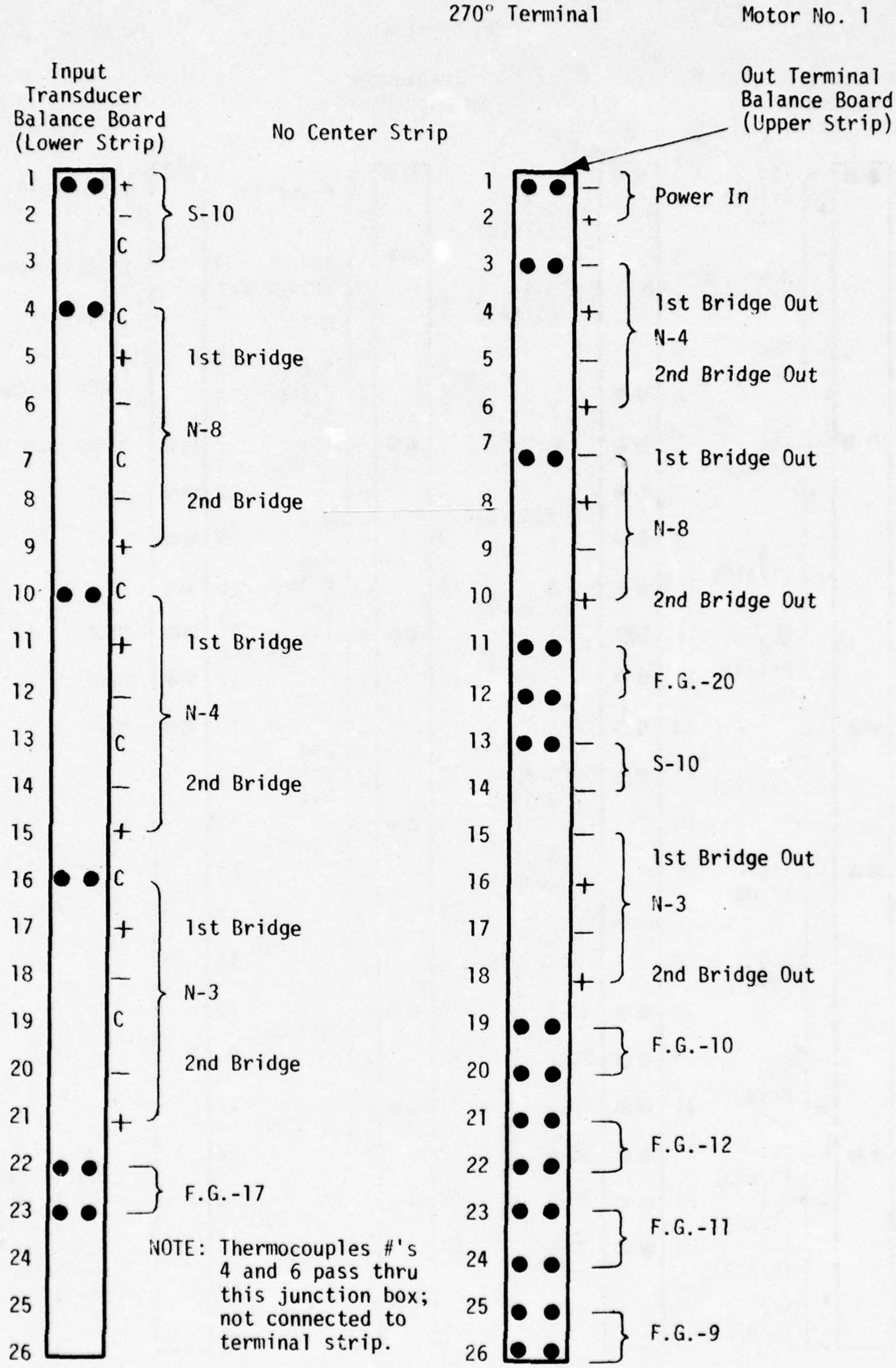


FIGURE F-14. TERMINAL IDENTIFICATION FOR 270° JUNCTION BOX

TABLE F-1

ASSIGNMENT OF GAGES TO RESPECTIVE JUNCTION BOXES

	ASPC NORMAL GAGE NO.	ASPC SHEAR GAGE NO.
0° J-Box	N-9	S-5
	N-10	S-6
		S-7
	N-11	S-8
		S-11
		S-12
90° J-Box	N-1	S-13
	N-2	S-14
180° J-Box	N-5	S-1
	N-6	S-2
	N-7	S-4
	N-15	S-9
270° J-Box	N-3	S-10
	N-4	
	N-8	

APPENDIX G

DESIGN OF ORIGINAL PORTABLE DAS INSTALLATION

DESIGN OF ORIGINAL PORTABLE DAS INSTALLATION

A. DESIGN AND INSTALLATION OF THE DATA ACQUISITION SYSTEM

1. 50 Channel Scanner

The data acquisition system for the Flexible Case tests which are shown in Figures 39 and 40 of Volume I consisted of the HP2010 series systems which utilizes a 2401 Hewlett Packard Integrating Digital Voltmeter (S/N A9C 2500020) as the digitizing element, along with the 2901A Input Scanner. The 2010 series is characterized by exceptional common mode and superimposed noise rejection, selectable integration line, and built in programming capability. The Dymec 2901A Input Scanner/Programmer scans 25 channels of inputs and programs all functions of associated systems. It was expanded to 50 channels with an auxiliary system which includes two banks of switches. System functions and measurement delay are programmed individually for each channel with a built-in pinboard. The maximum scanning rate is 12 channels/second.

2. Integrating Digital Voltmeter

The analog to digital converter on the 2401 integrating digital voltmeter features floated and guarded input and is average reading, yielding an effective common mode rejection better than 140 DB at all frequencies, including DC. Since they are average reading and fully guarded, it greatly reduces superimposed noise errors and common mode noise errors.

3. Digital Recorder

An HP Model 562A Digital Recorder (AGC-247-00863), the recording system used, is a solid state electromechanical device which provides a printed record of digital data. Its accuracy is identical to the input device used. Printing rate is 5 lines/sec and it has column capacity of 11 digits. The system accuracy is rated at DC accuracy of .01% rdg or $\pm$ .005% full scale.

4. Data Acquisition System

A flow diagram of the stress gage connected to the data acquisition system inside the trailer is shown in Figure G-1. This system scans multiple analog input signals, converts them to digital form and visually displays and permanently records the measurements. All instruments are rack-mounted as shown in Figure 39 of Volume I and include the following: Dymec Scanner and Printer System, integrating digital voltmeter, CEC oscillograph, Brown Multipoint Temperature Recorder, a patch and junction panel for parallel monitoring, and two banks of switches. The instrumentation layout when rack-mounted in the trailer is given in Figure G-2.

The input scanner and the integrating D.V.M. and the printer were periodically calibrated by PATO Calibration Laboratory using the voltage substitution calibration method.

5. Instrumentation Trailer

A large van-type utility trailer (Figure G-3), approximately 30 feet long by 8 feet wide, was used to house all instrumentation for monitoring and recording all tests in the various phases of the Flexible Case Program. Power to the trailer was provided by a 3 phase 440 volt step-down transformer. Power was then routed to a 30 amp power panel with circuit breaker. Output cables, which were attached to the junction boxes, were routed through an opening in the floor of the trailer to termination points. They were then patched to their respective channels.

6. Interconnecting Network

The interconnecting network for the D.A.S. consists of individual cables and connectors for each type of sensor. The wiring diagrams for the various cables and connectors are presented in the following figures:

Figure G-4	Event Gage Cable
Figure G-5	Strain Gage Single Leg Cable
Figure G-6	Bridge Excitation Cable
Figure G-7	Copper Constantan Thermocouple Cable
Figure G-8	Stress-Strain Cable for Full Bridge
Figure G-9	Typical Stress Gage Wiring From Panel Termination to D.V.M.

B. OPERATIONAL PROCEDURES

The operating procedure for data sampling of the data acquisition system is as follows:

1. Digital Voltmeter Switches

Range - .1V
Function - Volt
Sample Period - .1 sec
Power Switch - ON
Sampling Rate - Set at pen mark on face of panel

2. Input Scanner/Programmer

Selector Switches - All depressed but #5 - This deselects Channel #5 and #30 from scanning or printout. Press the reset switch which selects the scanner to home and then press the function switch labeled Single Scan.

Channel Selector Panel

All switches in the UP position to acquire Channels 1-25
All switches in the DOWN position to acquire Channels 26-50

3. Harrison 28V power supplies in rack on right

P.S. #1 - ON
P.S. #2 - ON
Voltage should read 28V on meters - don't adjust unless reading is off by more than .1 V.

24 Point CC Temperature Recorder

Speed Switch - High Mode

Printer

Power - ON
Record - ON when printout is desired

Data consists of approximately 50 permanently connected input channels plus 10 more that must be independently plugged into place of the first 10 inputs to acquire these extra channels. All channels have correlation identification in the layout book plus the extra ten channels have ID markers on the cables.

Record the 50 input channels using the selector switching panel, note the time and date plus the temperature from the 24 point recorder on the printout paper. Also, mark the time and date on the temp. recorder when it is started and stopped.

C. D.A.S. SPECIFICATIONS

1. General

The specifications for the total Data Acquisition System are listed in Table G-1.

2. Integrating Voltmeter - H.P. Model 2401C. Specifications for the integrating voltmeter used in the D.A.S. are listed as follows:

DC voltage measurements, noise rejection: Overall effective common mode rejection: 140 dB at all frequencies 160 dB at dc (0.1 second sample period); superimposed noise rejection; more than 20 dB at 55 Hz for 0.1 second sample period, increases 20 dB per decade increase in frequency, infinite rejection at frequencies evenly divisible by 10.

Input circuit: Type: Floated and guarded signal pair, may be operated up to 500 V above chassis ground; ranges: 5 from 0.1 to 1000 V f.s., selection by front-panel switch or remote circuit closure to ground, polarity sensed automatically; over-ranging: To 300% f.s. except 1000 V range; overload: Range automatically switched to 1000 V at 310% f.s., reset by next read command; input impedance: 10 M Ω on 10, 100, 1000 V ranges, 1 M Ω on 1 V range, 100 k Ω on 0.1 V range, <150 pF on all ranges.

Absolute accuracy: 0.01% of reading ± 0.005% f.s. ± 1 digit at 25°C; temperature coefficient ± 0.001% of reading per °C, 10 to 40°C.

Internal calibration source: ± V standard for self-calibration; maintains rated accuracy for 6 months after initial calibration to 0.002% at 25°C.

Measurement speed: Fixed sample periods of 0.01, 0.1 or 1 sec selected by front-panel switch or remote circuit closure to ground.

Resolution: Depends on sample period; max 1μ V per digit.

Autoranger (optional) voltage ranges: Automatically selects range from 5 input ranges of standard instrument (0.1 V to 1000 V f.s.) .34 ms max range change time.

DC voltage integration: Input signal is integrated over selected sample period; using fixed sample period, integral is average of input.

Frequency measurements: 5 Hz to 300 kHz, optionally to 1.2 MHz; gate time 0.01, 0.1, 1 sec or manual; accuracy: ± 1 count ± time base accuracy; time base: Stability at constant temperature (± 5°C) is ± 2/10^6/ week, temperature effect ± 100/10^6 over range 10 to 50°C, provisions for external time base; display time: Variable from 0.2 to 7 sec, or held until reset; input sensitivity: 0.1 to 100 V rms; impedance: 1 MΩ shunted by 150 pF.

Period measurements (optional): 1, 10, and 100 periods; 5 Hz to 10 kHz; display is in ms; resolution referred to single period; 1 period, 100 μsec; 10 periods, 10 μs; 100 periods, 1 μsec; accuracy is ± 1 count ± time base accuracy ± trigger error divided by number of periods. Sensitivity and impedance same as frequency measurements.

3. Digital Recorder - H.P. Model 562A

Specifications for the digital recorder used in the D.A.S. are listed as follows:

Accuracy: Identical to input device used.

Printing rate: 5 lines per second, maximum.

Column capacity: To 11 columns (12 available on special order).

Print wheels: 12 positions, numerals 0 through 9, a minus sign and a blank; other symbols available.

Input Requirements:

Data input: Parallel entry, BCD (4-2-2-1, 8-4-2-1, 2-4-2-1) or 10-line, see Options; (1) state must differ from "0" state by at least 4 Volts but by no more than 75 Volts.

Reference voltages: BCD codes require both "0" and "1" state references; 10-line codes require reference voltage for "0" state; reference voltages may not exceed ± 150 V to chassis; input impedance is approximately 270 k ohms.

Hold-off signals: Both polarities are available simultaneously for BCD codes and are diode-coupled; 10 mA maximum load +15 V open circuit from 1 k source, -5 V open circuit from 2.2 k source (160 msec hold-off is provided for 10-line codes).

Print command: + or - pulse, 4.5 to 20 volts amplitude, 1 V/μs minimum rise time, 20 μs or greater in width, ac coupled.

Analog output (optional): (from 4-2-2-1 or 8-4-2-1 boards) accuracy is ± 0.5% of full scale or better; 100 mV for potentiometer recorder; 50 k ohm minimum load resistance; 1 mA into 1.5 k ohm maximum for galvanometer recorder.

Transfer time: 2 ms for BCD codes.

Paper required: HP folded paper tape (15,000 prints per packet with single spacing) HP Stock No. 560A-131A or standard 3-inch roll tape.

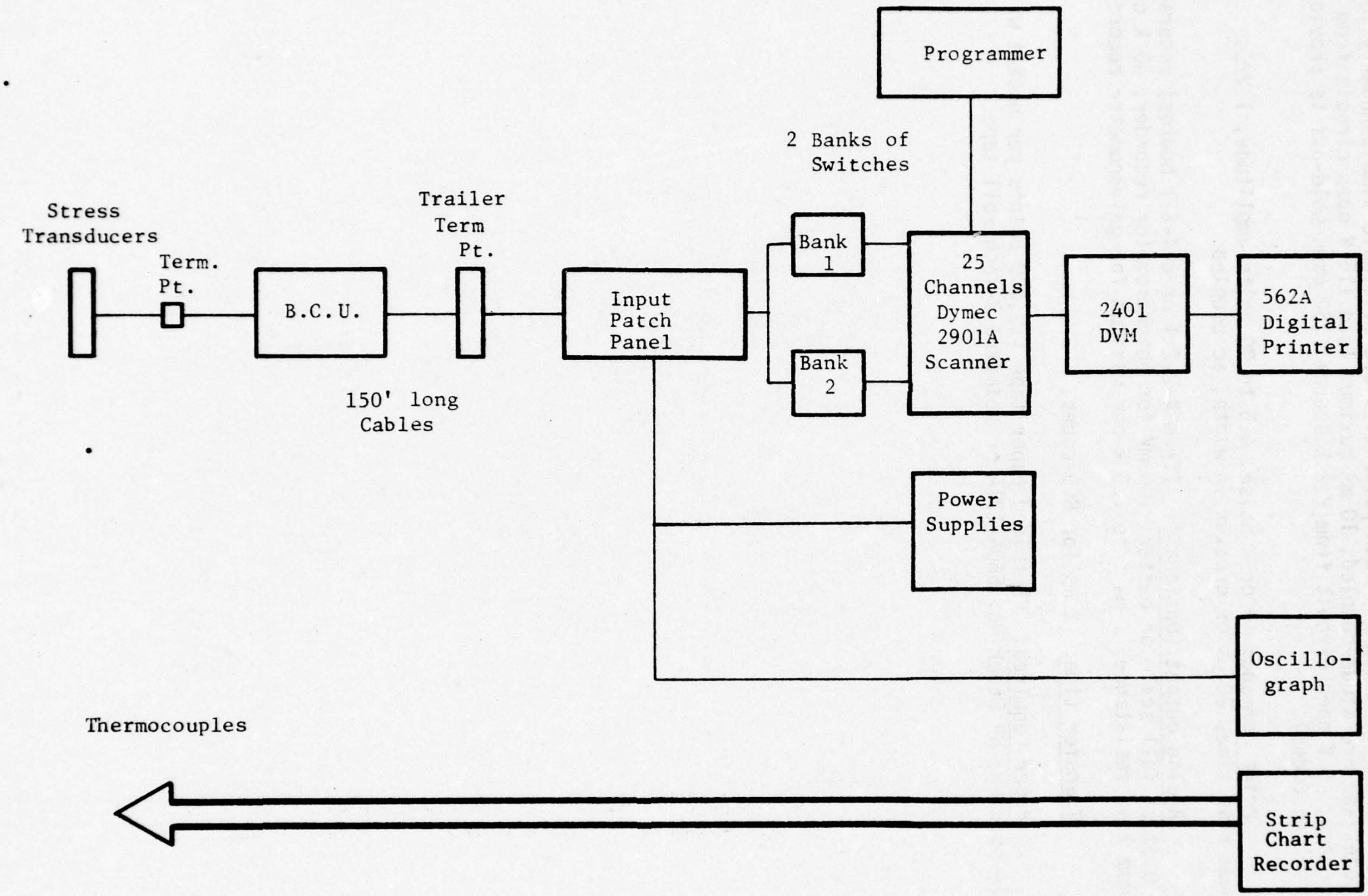


FIGURE G-1. BLOCK DESIGN OF PORTABLE D.A.S.

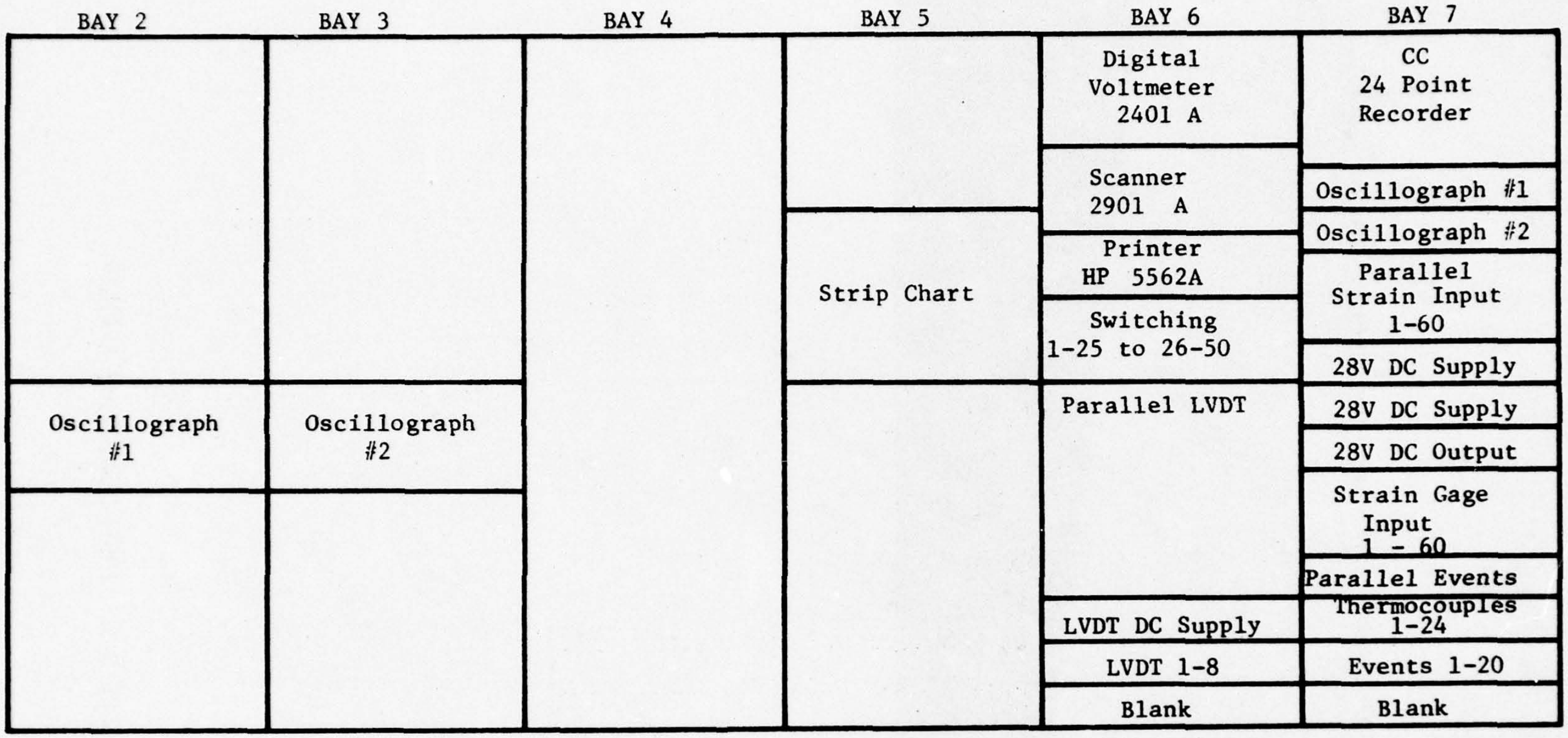


FIGURE G-2. INSTRUMENTATION LAYOUT WHEN RACK MOUNTED

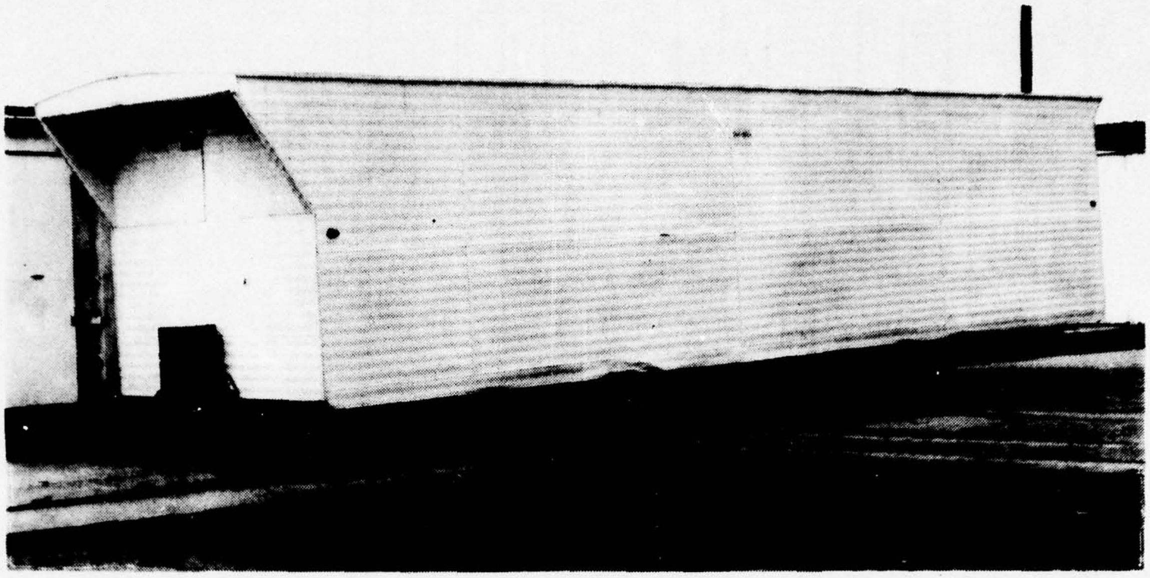


FIGURE G-3. INSTRUMENTATION TRAILER

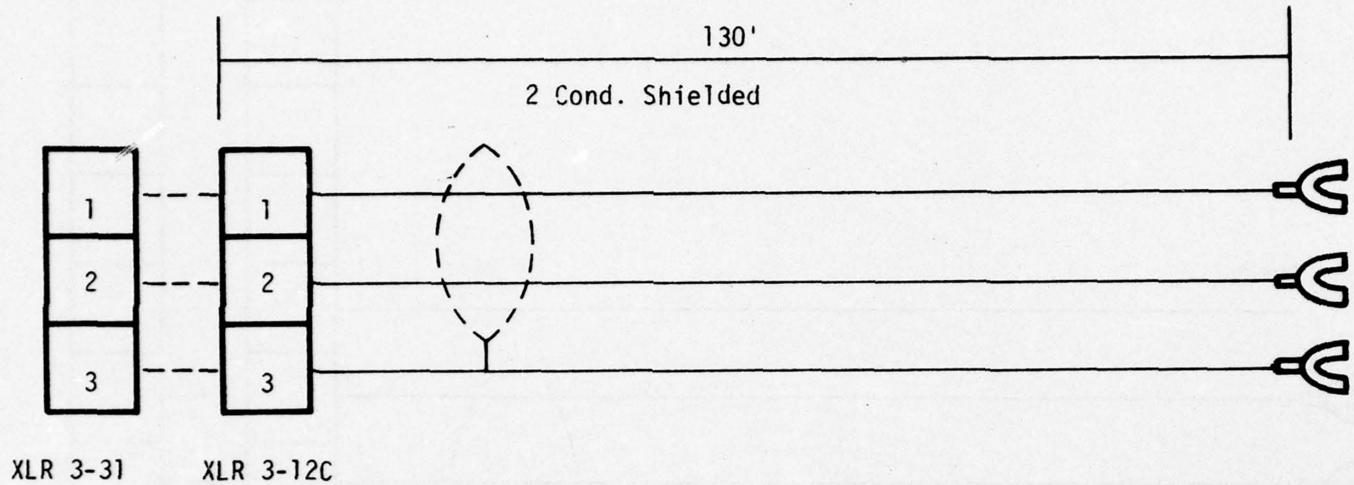


FIGURE G-4. EVENT GAGE CABLE

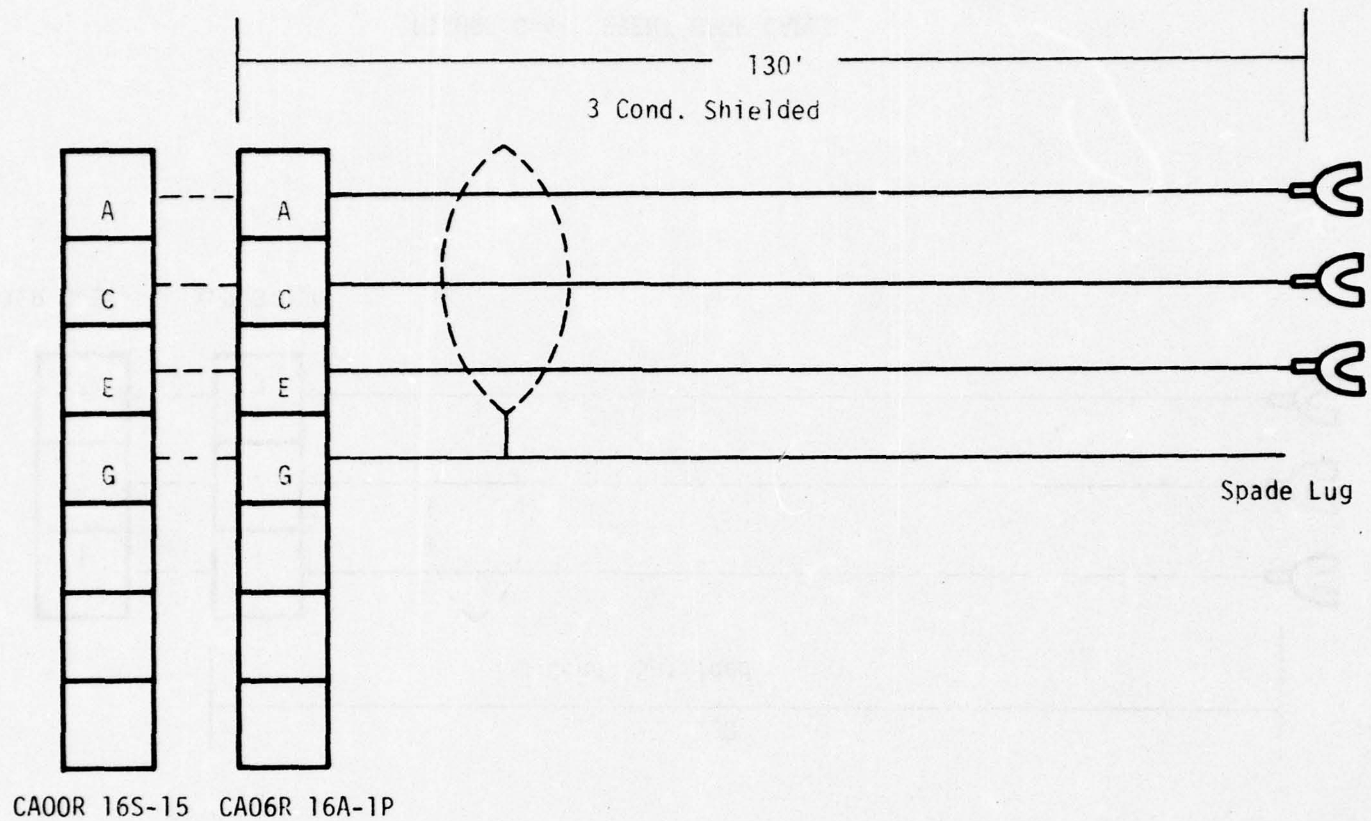


FIGURE G-5. STRAIN GAGE - SINGLE LEG CABLE

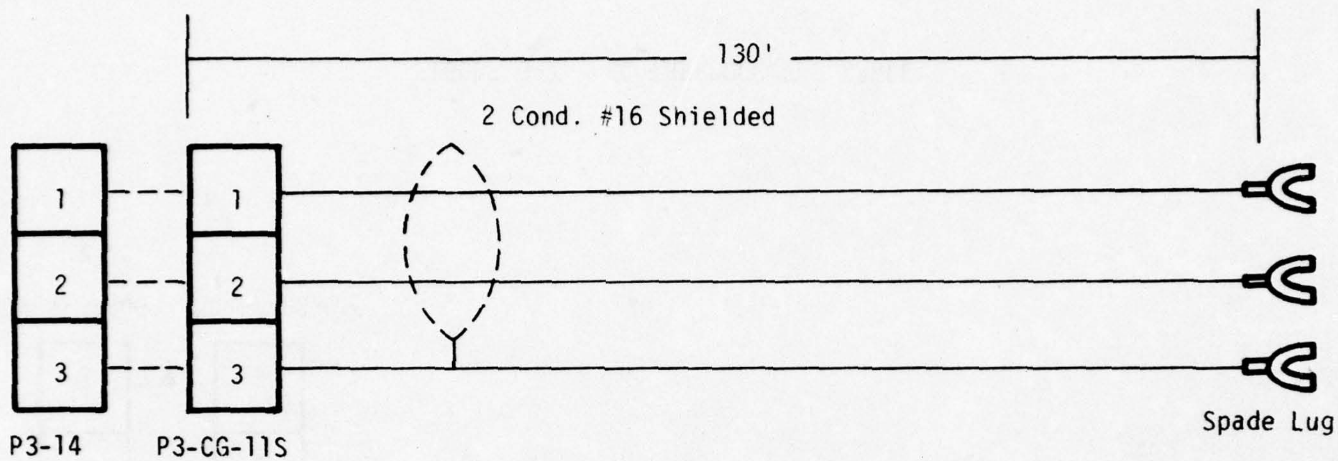


FIGURE G-6. BRIDGE EXCITATION CABLE

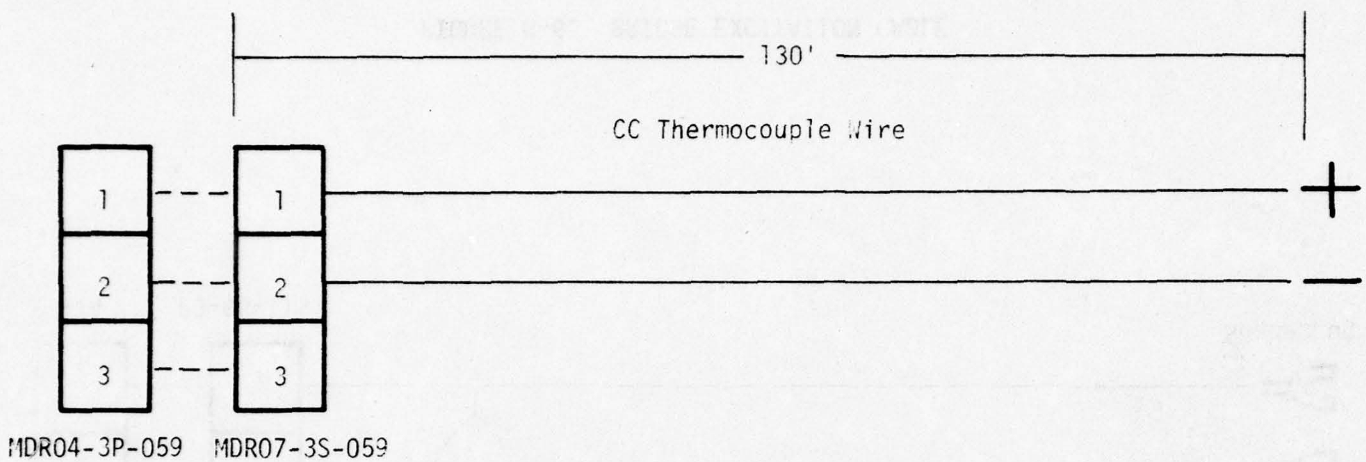


FIGURE G-7. CC THERMOCOUPLE CABLE

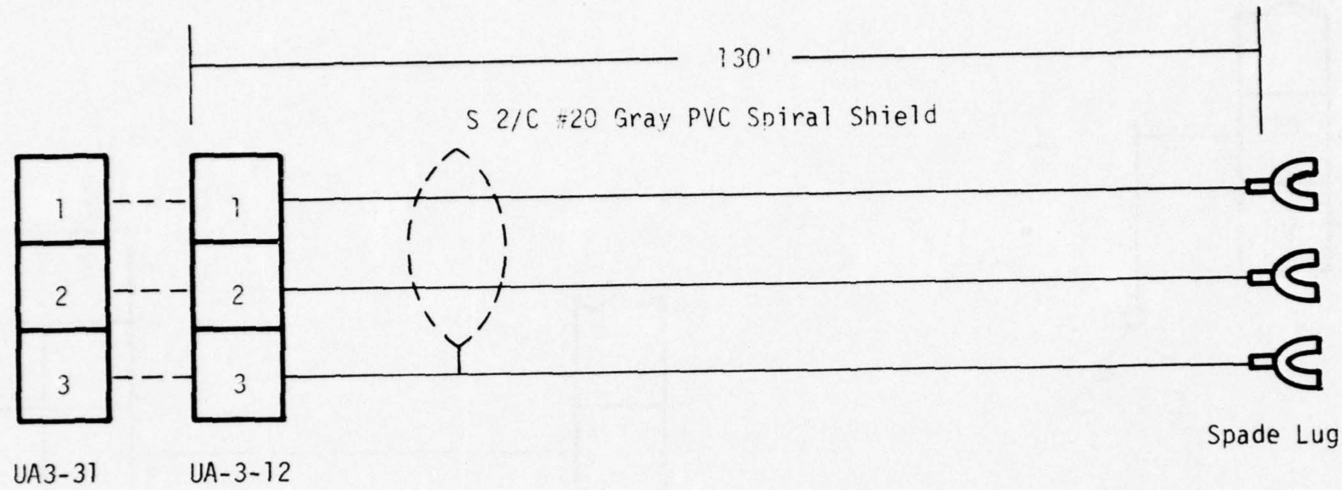


FIGURE G-8. CABLE FOR FULL BRIDGE

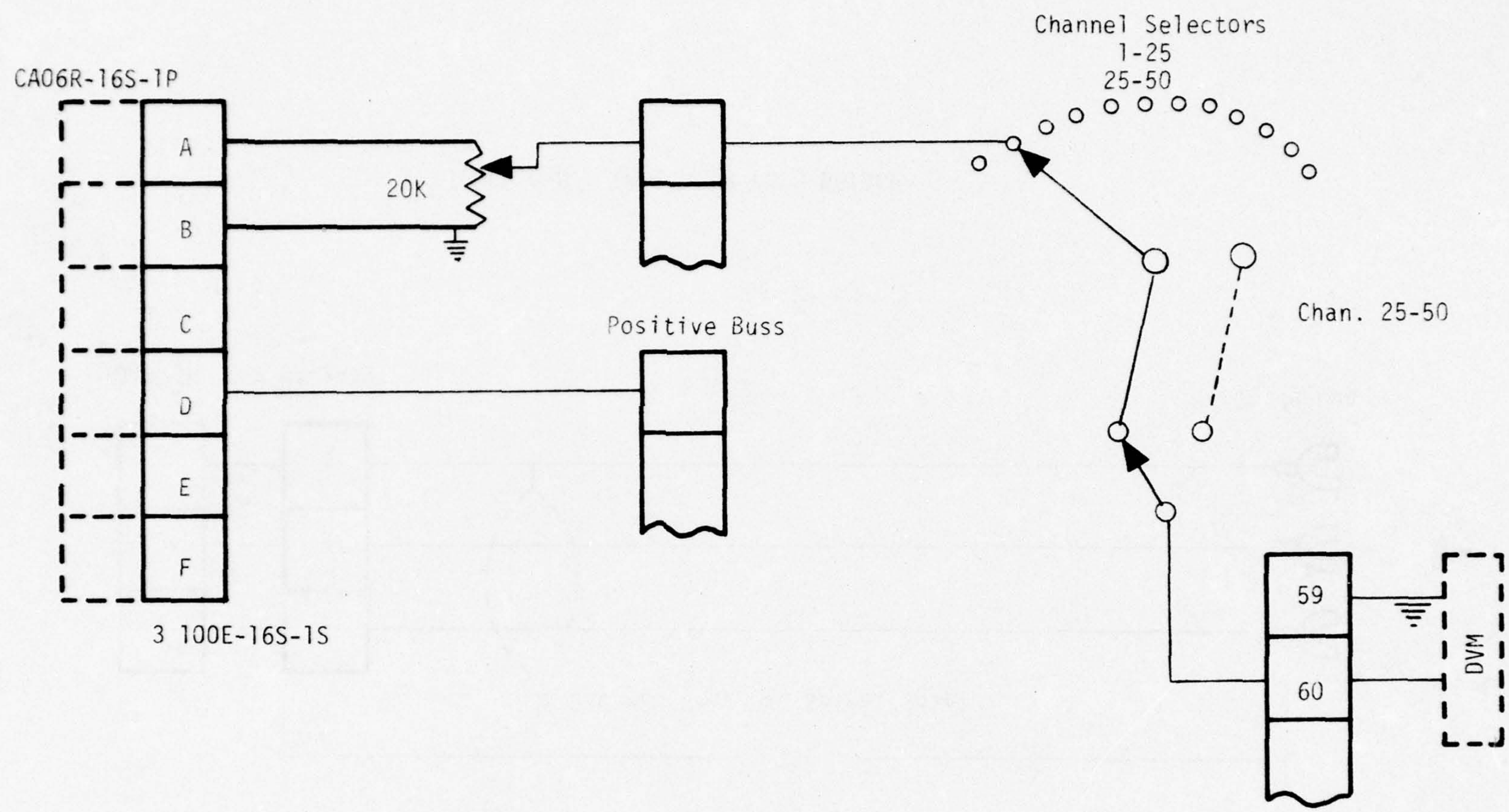


FIGURE G-9. TYPICAL STRESS GAGE WIRING FROM PANEL TERMINATION TO DVM

TABLE G-1

GENERAL SPECS FOR D.A.S.

Number of input channels	Up to 25 3-wire inputs		
Programming	Built-in; all DVM functions, delays		
DC measurement	100 mV to 1000V, 5 ranges, ± 750 V max., resolution determined by gate time		
AC measurement	100 mV to 1000V, 5 ranges, 750V max., resolution determined by gate time		
Ohms measurement	100 Ω to 10M Ω, 6 ranges, .001 resolution on 100 Ω range.		
Frequency measurement	5 Hz to 300 kHz, resolution determined by gate time.		
Period measurement	5 Hz to 10 kHz, resolution determined by gate time.		
DC accuracy	100 mV: .01% rdg ± .01% fs; other ranges: .01% rdg ± .005 % fs		
Measurement speed (max. dc volts)	6 chan/sec	9 chan/sec	54 chan/min
	Digital Printer	Punched Tape	Typewriter

APPENDIX H

SUMMARY OF TEST DATA FROM THE ORIGINAL PROGRAM

SUMMARY OF TEST DATA FROM THE ORIGINAL PROGRAM

A. SUMMARY OF GAGE DATA OBTAINED FROM MOTOR NO. 1 IN THE ORIGINAL TEST PROGRAM

1. Introduction

A complete log of the normal stress gage output data for Motor No. 1 beginning with the initial laboratory calibrations through the end of the thermal cycling tests, was prepared and is discussed in Section 3. This log represents the output from 24 independent bridges, since each of the 12 normal stress gages has two. In addition to the data log presentation, the following major tests and the resulting normal stress and shear gage data are discussed in detail as follows:

Section 4 - Pressure Calibration of Motor No. 1
Section 5 - Cure and Cooldown Data
Section 6 - Aging of Propellant Grain at 110°F
Section 7 - Thermal Cycle

2. Description and Location of Stress Gages

The 12 normal stress gages and the 14 shear stress gages were located in Motor No. 1 as shown in Figures 22 to 27 of Volume I. N_1 through N_4 were the 450 psi normal gages located on the aft dome between the equator and the nozzle boss. N_5 through N_{11} were the 150 psi normal gages placed at selected locations in the barrel section of the motor. D2N is the normal gage for the 3-D gage located near the forward equator. Shear gages S-1 through S-8 were located on the aft dome between the equator and the nozzle boss at the 0 to 180° plane. Shear gage S-13 is located near the forward equator and shear gages S-9, 10, 11, 12 and 14 were located on the barrel section. Shear gages S-12 and S-14 were rotated 90° to sense dynamic response.

3. Output Data Review

Output data from all normal stress gages measured in Motor No. 1 are tabulated in Table H-1 and plotted in Figure H-1 and Figures 43 and 44 of Volume I. The data began with the potted gage calibration made at Konigsberg Instruments in the form of zero load output vs temperature. Then all the gages were calibrated in the tensile mode at ambient temperature by means of a vacuum chamber. It was at this point that noticeable zero load output changes occurred. Following the vacuum calibrations, the potted gages were installed in the empty chamber. The first test performed on the empty chamber after installation of the gages was a 15 psig pressurization for checkout of all the gage circuits and to check the normal gage responses.

In an attempt to obtain "zero load" output data at approximately 30°F for subsequent use in translating the loaded motor data to stresses, local areas of the chamber were cooled with dry ice. The dry ice was placed inside the chamber, and the chamber was rotated to bring it in proximity to the area to be cooled. The gage temperatures were taken as indicated by the nearest internal thermocouple.

The chamber was then lined and processed through the manufacturing operations. It was finally lowered into the casting bell and the instrumentation was connected. Large offsets in the zero load readings were recorded.

The propellant was cast and the cure pressure of 15 psig was applied. All the gages were sampled periodically during the 12 day propellant cure period and during the subsequent four days cooldown period. After core extraction two pressure calibrations to 50 psig were conducted as shown in Figure H-1 and in Figures 43 and 44 of Volume I. Then data for the four months aging at 110°F and the thermal cycling between 60 and 110°F were obtained as shown in Figure H-1 and Figures 43 and 44 of Volume I.

4. Pressure Calibration for Full Scale Motor No. 1

a. Test Results

The motor was pressurized in accordance with the Test Plan with gaseous nitrogen in 10 psig steps to 50 psig at 80°F to verify that all instrumentation was functional and that polarity was correct. In addition reference points were provided for future verification of calibration and data reduction and to establish the basis for an in-situ gage calibration from which gage sensitivity factors could be calculated. In the first pressure calibration run the sensitivity of the D.A.S. was not set to resolve the output voltages to the nearest 0.01 mv, so those data are not presented here.

A second pressure calibration run was conducted. Test data from the second run are tabulated in Table H-2 and the resulting gage sensitivities of the normal stress transducers are given in Table H-3. The results from this second run are shown graphically in Figures H-2 through H-10. Some of the outputs from the shear gages (S-1, S-2, S-7, S-8, S-14) are not linear functions of pressure. This may be attributed to the fact that the smaller shear stress levels may be more related to case deformation than to applied pressure. When the gage output signals were converted to normal and shear stresses (Figures H-11 and H-12), two of the normal stress gages N2 and N3 located at the aft end of the dome respond to only a portion of the applied pressure. Similarly, this may be partly due to local case deformation. The shear stress data from Figure H-12 ranges from a maximum at gage S-13 to a minimum at gage locations S-2, S-4, and S-14. It should be noted that these data are simple conversions of the gage output into stress and do not take into account effects due to grain attenuation, gravity, or sensitivity of gage due to normal pressure.

The post cure pressure calibration test measurements from the L.V.D.T.'s located in the bore surfaces are shown in Table H-4. A graphic illustration shows the bore deflection, Figure H-13.

b. Reanalysis of Shear Gage Data

Two different techniques for interpreting the data obtained from the shear gages during pressure tests on the full scale motor were evaluated. Because the response of the shear gages is influenced by hydrostatic pressure and the normal stress at the gage location as well as by the shear stress at that point, the best approach is to employ an equation which sums these separate effects and enables the shear component to be determined. The difficulty with this approach is that the polarity of the response of the shear sensor to the separate components must be determined prior to casting the grain otherwise it will not be known if the pressure and shear effects add or subtract. Since the polarities of the various components were not determined for the full-scale motor, this approach could not be employed.

The second approach to interpreting the shear gage data made use of the shear gage response to hydrostatic pressure measured before the grain was cast. These data were obtained with the gages mounted inside the motor case and connected to the output circuits in the same manner as for the later pressure tests on the motor after the grain was cast. During the pressure tests on the shear gages inside the motor without the grain, the gage responds to the pressure and pressure normal stress in a realistic fashion but without the additional stresses induced by the propellant grain. Consequently the response of the shear gages to pressure without the grain can be subtracted from the gage response with the grain to provide the shear stress values caused by the grain.

When this technique for shear gage data analysis is employed there should be no polarity problems. However, because the wiring was disconnected from the motor after the pressure calibration tests and subsequently re-connected for the later pressure tests of the complete motor, the problem of whether or not the pressure and shear effects add or subtract still remains. Because of this problem, having determined the sensitivities of the shear gages to pressure (see Figures D-5 and D-6) the effects of adding and subtracting this pressure term were calculated and are plotted in Figures H-14 through H-16.

The data from gages S-13 and S-9 show little difference if the pressure output is added or subtracted; but S-12 shows a marked effect. Because gage S-12 is mounted at 90° to the axis of the grain, it is likely that the smaller of the two curves is the correct one for gage S-12.

When considering the data shown in Figures H-15 and H-16, it should be remembered that gages S-1 and S-5 are at similar locations in the motor, as are gages S-2 and S-6, gages S-3 and S-7 and gages S-4 and S-8. We may, therefore use similarity in the gage outputs to define the correct curves for these gages. From this approach we may deduce that for gages S-1 and S-5, the maximum data curves are the correct ones; whereas for gages S-2 and S-6, the two curves labeled minimum are the correct ones and give almost identical data. Similarly, for gages S-3 and S-7, the maximum value curves appear correct, and for gages S-4 and S-8, the minimum curves are the correct curves.

5. Cure and Cooldown Data

The gage data from the calibration tests were committed to magnetic cards for easy insertion into the memory of the HP 9810A data analysis system. To provide a better fit to the zero stress calibration data curves a second order (parabolic) equation of the type;

$$S_0 = a + bT + cT^2 \tag{H-1}$$

was fitted to each set of data and the coefficients a, b and c, for each gage were stored in the memory. Once the temperature is known, the zero load gage output reading is readily calculated and subtracted from the current gage reading in order to determine the stress or strain value.

To calculate the stresses, the operator keys in the gage number, output signal and temperature and the stress value is then printed out and simultaneously stored in the memory for future use in stress-temperature of stress-time plots.

Typical plots of the stresses calculated from the gage outputs as a function of time in days are presented in Figures H-17 through H-20 where data from shear gages S-1, S-2, S-10 and S-13 are shown, and in Figures H-21 through H-24 where the data obtained from gages N2-1, N4-2, N9-1 and N10-1 are shown.

With the single exception of shear gage S-13, which showed the highest shear stresses on thermal cooldown, the shear gages all showed very low thermally induced shear stresses of the order of 1 to 3 psi maximum. Gage S-13 located at the end of the forward boot showed a stress of 10 psi at the end of cure and cooldown. (This same gage showed the highest pressure induced shear stresses.)

Figures H-21 and H-22 show the data from 450 psi gages, which were not really intended for thermal stress measurement. However, the data appear reasonable and the correlation from one half bridge circuit to its twin output is a simple means of checking the data.

Figures H-23 and H-24 show data from 150 psi gages and these data appear to be very good. Comparison between the data from one half bridge to the other half bridge circuit is usually very good and this is particularly so in the case of gages N10-1 and N10-2, where the data are almost identical.

6. Aging of Propellant Grain at 110°F

Following instrument calibration, Motor No. 1 was stored for four months at 110°F. Including the one month consumed during the preceding tests at 80°F, the motor was more than five months old at the end of the storage time. The objectives of this storage period at 110°F were to minimize the effect of post-cure hardening reactions on the stress-free temperature of the ANB-3066 propellant and to ensure that the stress-free temperature was stabilized at 110°F to provide a reliable reference condition. The aging test was conducted in conformance with AGC test plan 1826-26-TP.

The test results obtained during the lengthy post-cure of Motor No. 1 at 110°F were analyzed in Figures H-25 through H-29 and are shown as follows:

> Test data for 1st week of aging test is shown in Table H-5; data for the 2nd to 6th week of aging in Table H-6, and data for the 7th to 11th week in Table H-7.

It was very difficult to detect a consistent trend from the various gage outputs. Some of the gages appear to have developed a significant thermal stress during the time spent at 70° prior to post-cure, and the subsequent heating of 110° did not reduce or eliminate this stress, this is particularly true of the normal stress gages.

However, there was little doubt that there was very little change in the stress field throughout the motor during the aging time; all the aging data being consistent and showing very small changes with time.

7. Thermal Cycling of Motor No. 1

The thermal cycle test for Motor No. 1 was conducted in conformance with the test plan and commenced on July 19, 1973. These measurements were intended to determine the extent of post cure hardening and the effective stress-free temperature of the grain. The motor was conditioned to five different temperatures for ten days each over the range from 60 to 110°F. A test period of at least 50 days was required.

a. Description of Test

The motor was kept in an environmental bay at Building 4637 in the Test Area for the temperature cycling. All the instrumentation cables exited from the bay to the portable DAS in the instrumentation trailer.

b. Test Sequence

The motor was initially stored for 12 days at 80 ± 5°F. The thermal conditioning timetable was as follows:

7/19 to 7/31	12 days at 80 ± 5°F
8/1 to 8/9	9 days at 60 ± 5°F
8/10 to 8/24	15 days at 110 ± 5°F
8/25 to 9/5	12 days at 80 ± 5°F
9/6 to 9/17	12 days at 60 ± 5°F
*9/18 to 9/20	3 days at 110 ± 5°F

c. Test Procedures

The test procedures used were as follows:

(1) Store the motor for 10 days at 80 ± 5°F
(2) Monitor the motor instrumentation.
(3) Condition the motor for 10 days at 60 ± 5°F and monitor all instrumentation.
(4) Repeat the above for the conditioning temperatures of 110° ± 5°F, 80 ± 5°F, and 60 ± 5°F.

d. Test Results

The thermal test data are shown in Table H-8.

Figures H-30 through H-47 present most of the thermal cycling test data obtained from the gages within full scale motor #1. Figures H-30 through H-37 show the normal stress data while Figures H-38 through H-47 show the shear gage data.

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* Additional test cycle.

Apart from the fact that almost all the data suggest the presence of a considerable amount of stress free temperature change coupled with stress ratcheting, the data are poor because the two halves of the same normal stress gage, i.e., the two dual bridge circuits on a single diaphragm show considerably different results. This fact reveals that the problem belongs to the gage because, clearly both bridge circuits must see the same stress so that they should give the same stress values. Examination of Figures H-30 through H-37 reveals that the two stress readings initially are reasonably close to each other but show increasing differences with aging. Some gages, notably gages N7-1 and N7-2 (Figure H-36), show a consistent trend towards a bigger difference in the two sets of data from the end of cure through aging at 110°F to the temperature cycling data. Other gages such as N1-1 and N1-2 show a large difference in their stress values at the end of cure and cooldown.

An examination of the shear gage data shows less indication of problems. While some of the gages clearly have incorrect zero stress values, there does not seem to be the tendency towards a continual drift in readings with aging time. Of course there are no dual shear gage circuits in the motor so that these types of change are much more difficult to detect.

The basic problem with the data seems to be a shift in the zero stress output of the gage with aging time. This may be demonstrated by plotting the gage output for the pairs of dual gages directly in millivolts and using an arbitrary vertical shift in the readings to obtain reasonable agreement of the two sets of data. The resulting data are presented in Figures H-48 through H-53 and it will be noted that, whereas there is a great difference between the gage outputs when converted into stress using the stress free gage readings from the pre-casting calibrations, the changes in gage readings in millivolts are very much closer. In fact the agreement is very good. These data could in fact be converted into stress readings by using an arbitrary zero stress value, at 110°F for example, and using the gage sensitivities to convert the changes in output into changes in stress. This approach supposes that there is now an essentially constant zero stress gage output across the temperature range of interest, which seems to agree with the experimental gage data.

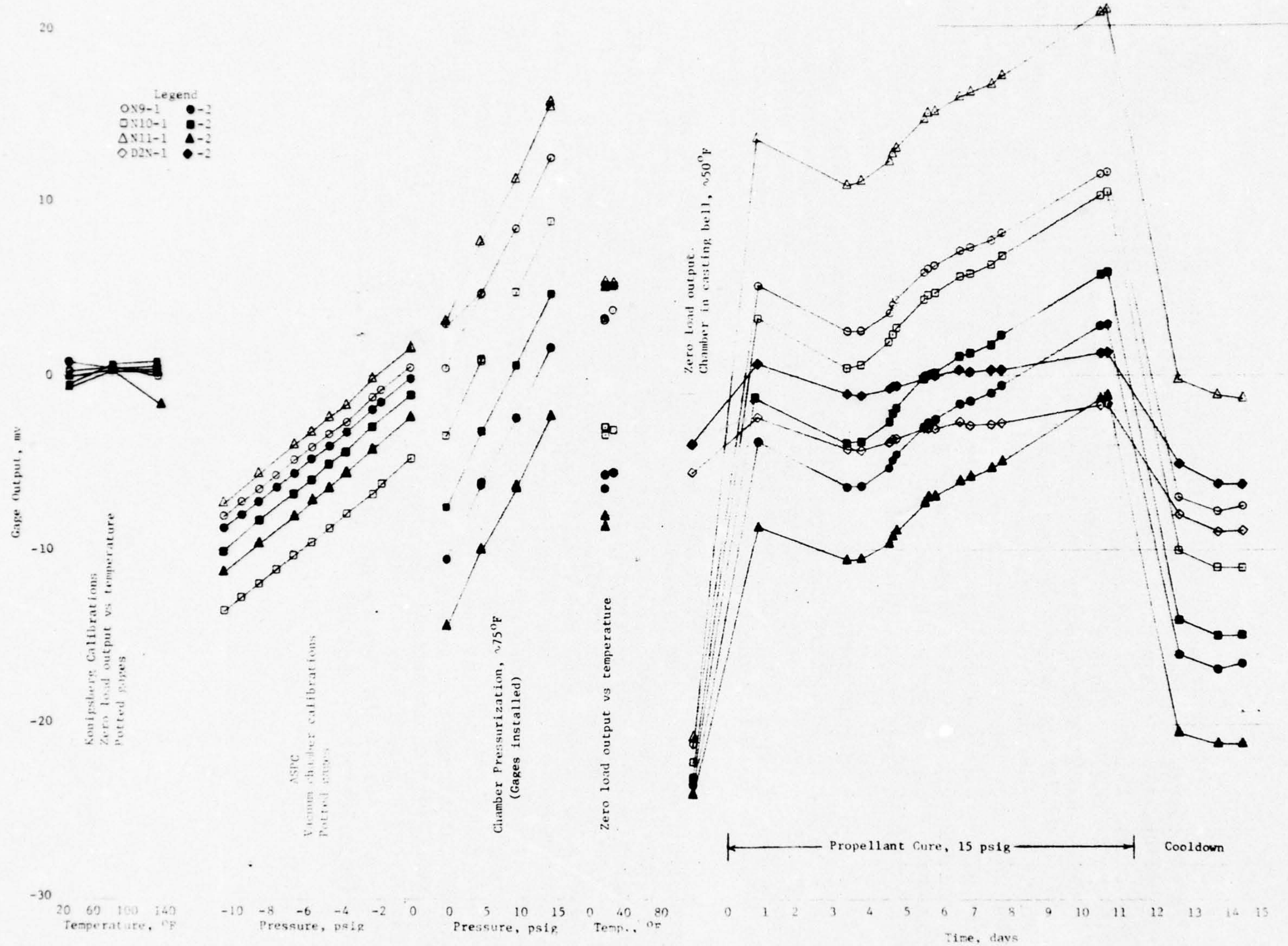


FIGURE H-1. OUTPUT LOG FOR NORMAL GAGES N9, N10, D2N

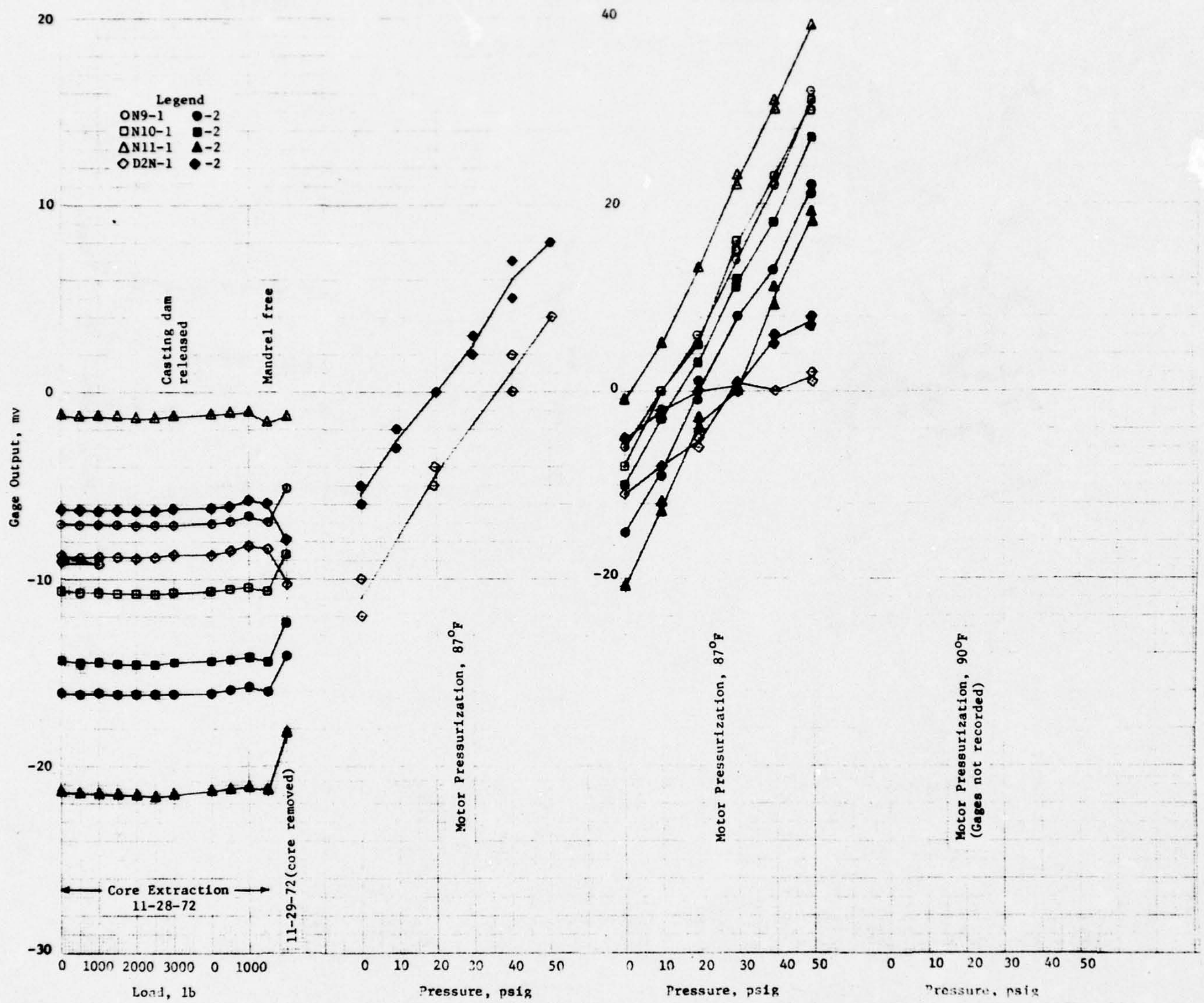


FIGURE H-1. OUTPUT LOG FOR NORMAL GAGES N9, N10, N11, D2N (CONT.)

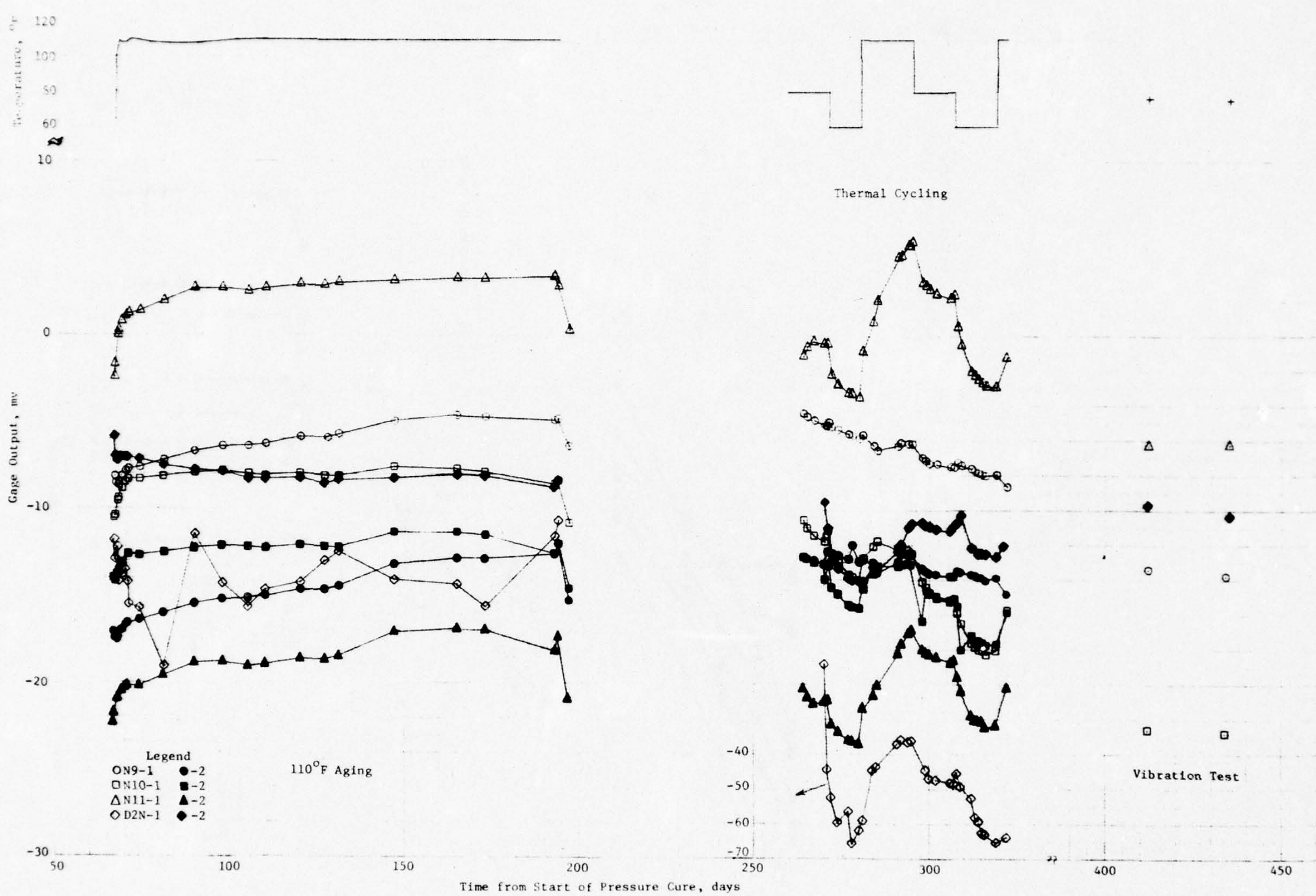


FIGURE H-1. OUTPUT LOG FOR NORMAL GAGES N9, N10, N11, D2N (CONT.)

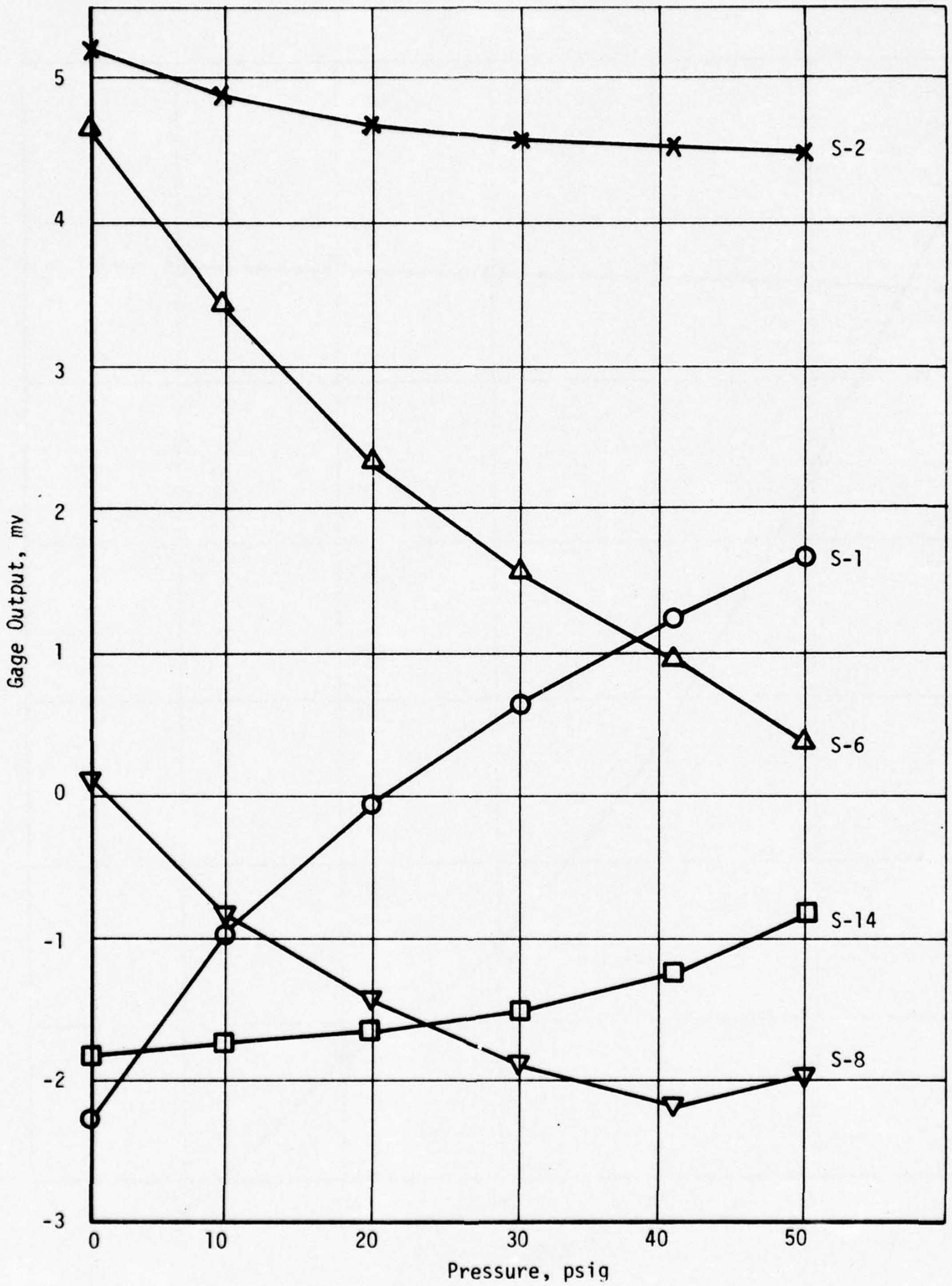


FIGURE H-2. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1

SHEAR GAGES S-1, S-2, S-6, S-8 AND S-14

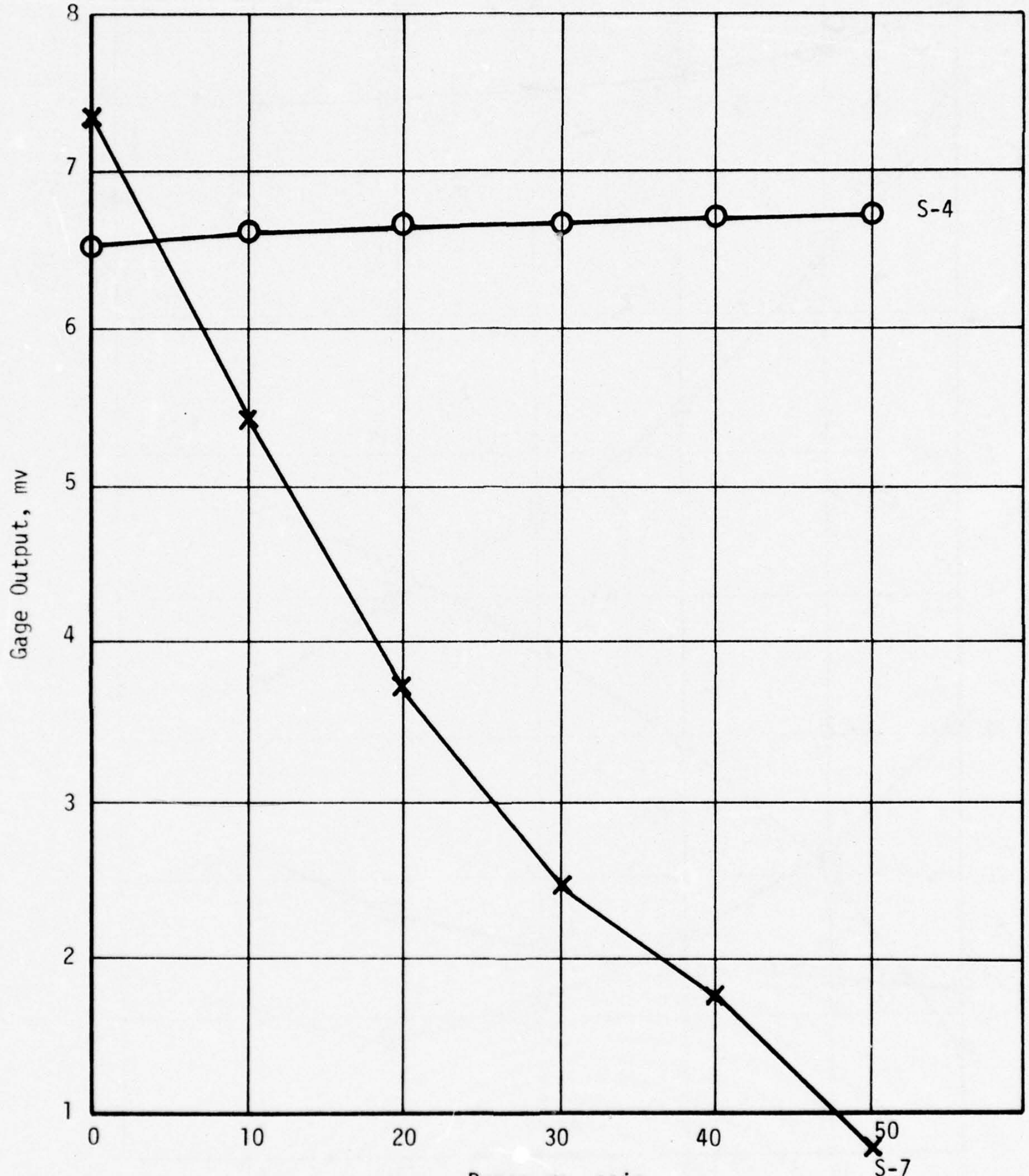


FIGURE H-3. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1 SHEAR GAGES S-4 & S-7

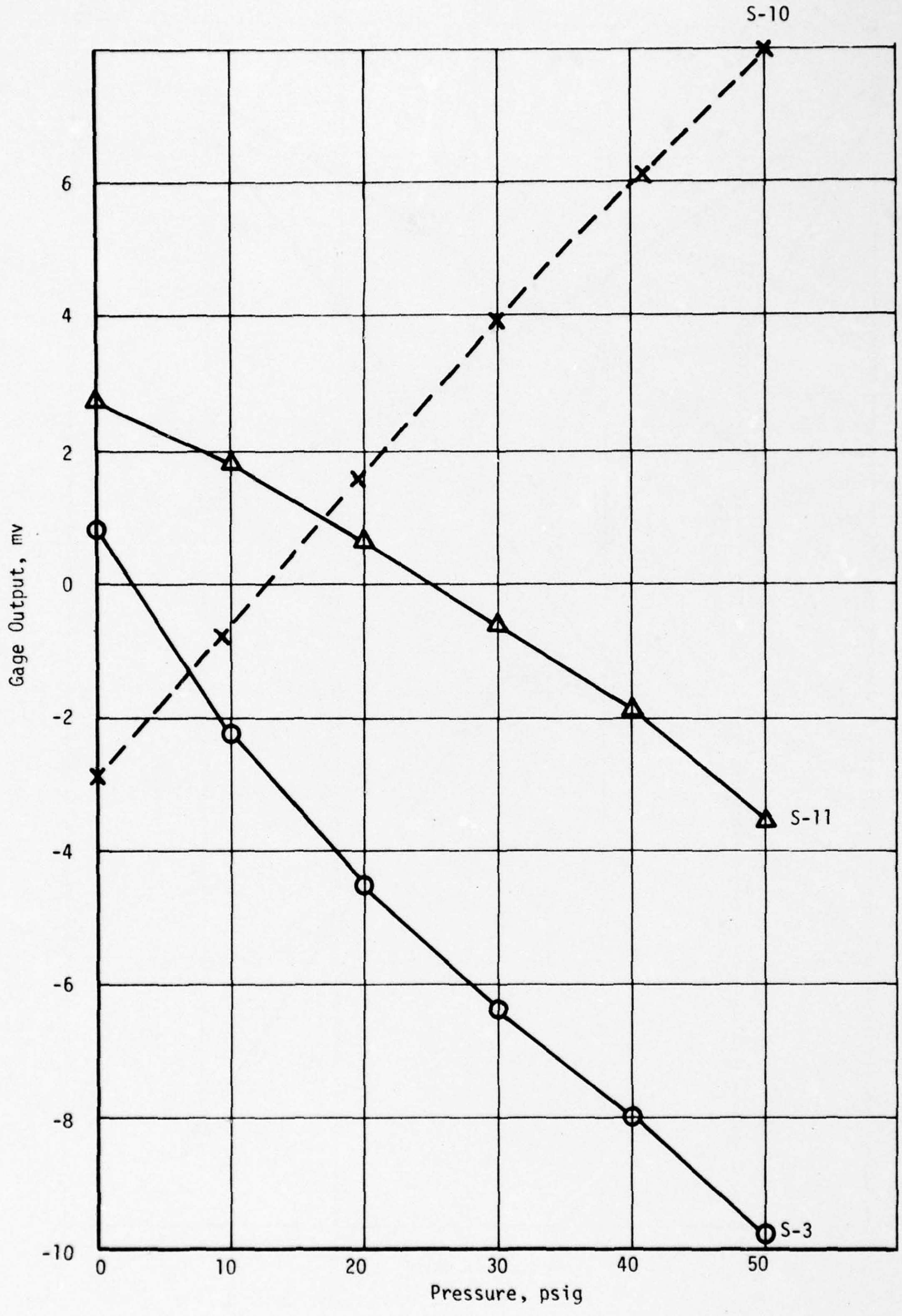


FIGURE H-4. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1, SHEAR GAGES S-3, S-10 AND S-11

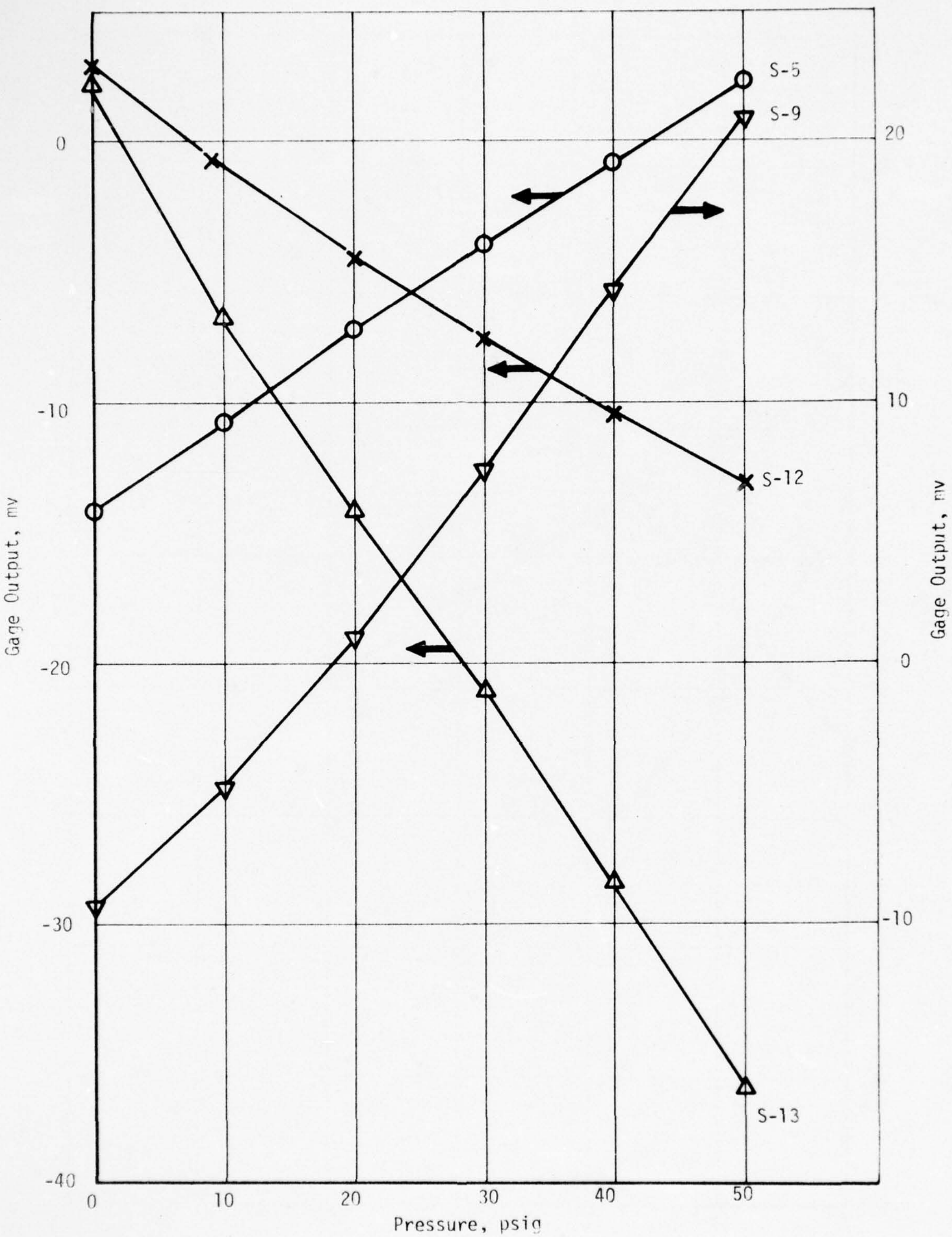


FIGURE H-5. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1, SHEAR GAGES S-5, S-9, S-12 AND S-13

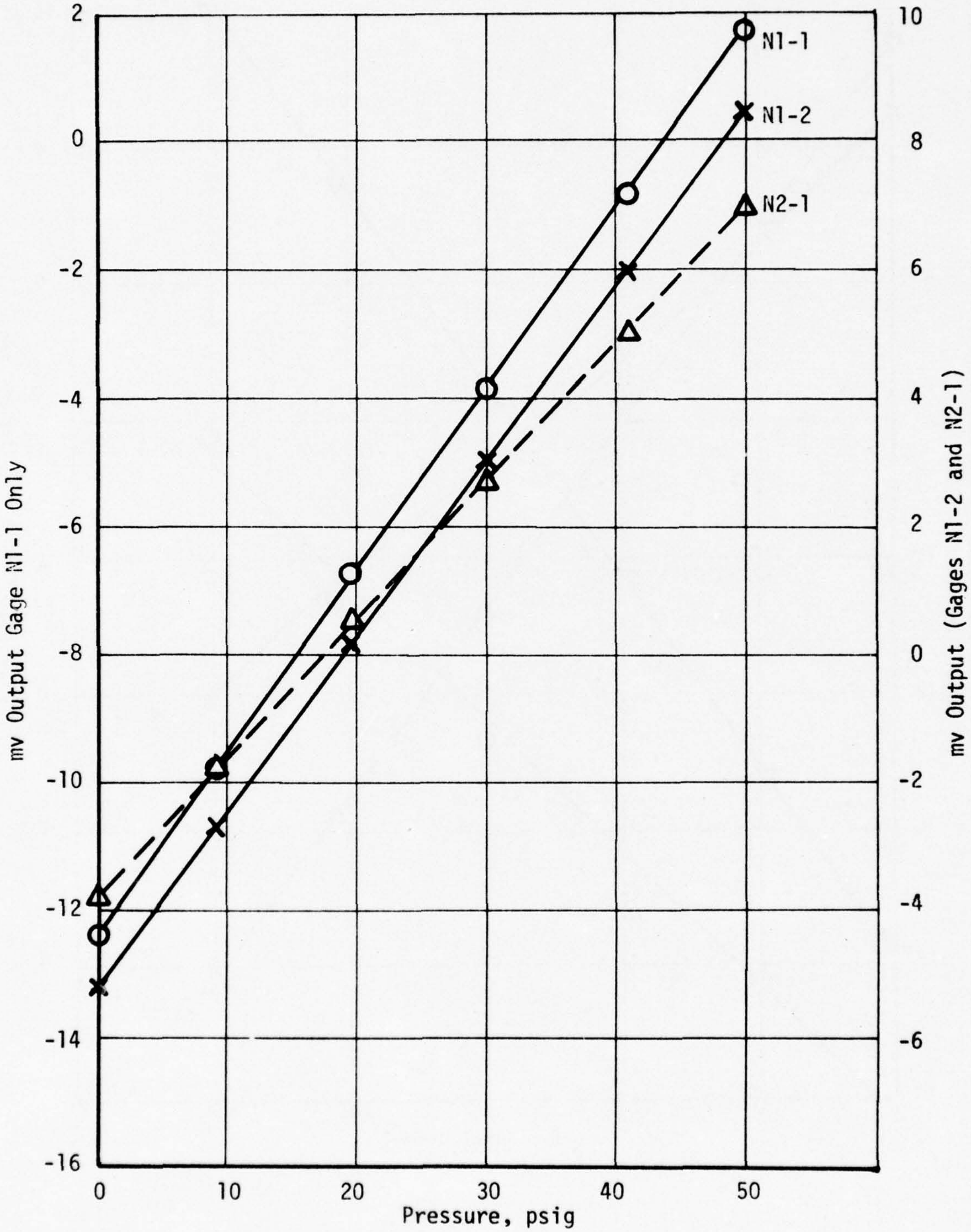


FIGURE H- 6. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1
450 PSI NORMAL GAGES N1 AND N2

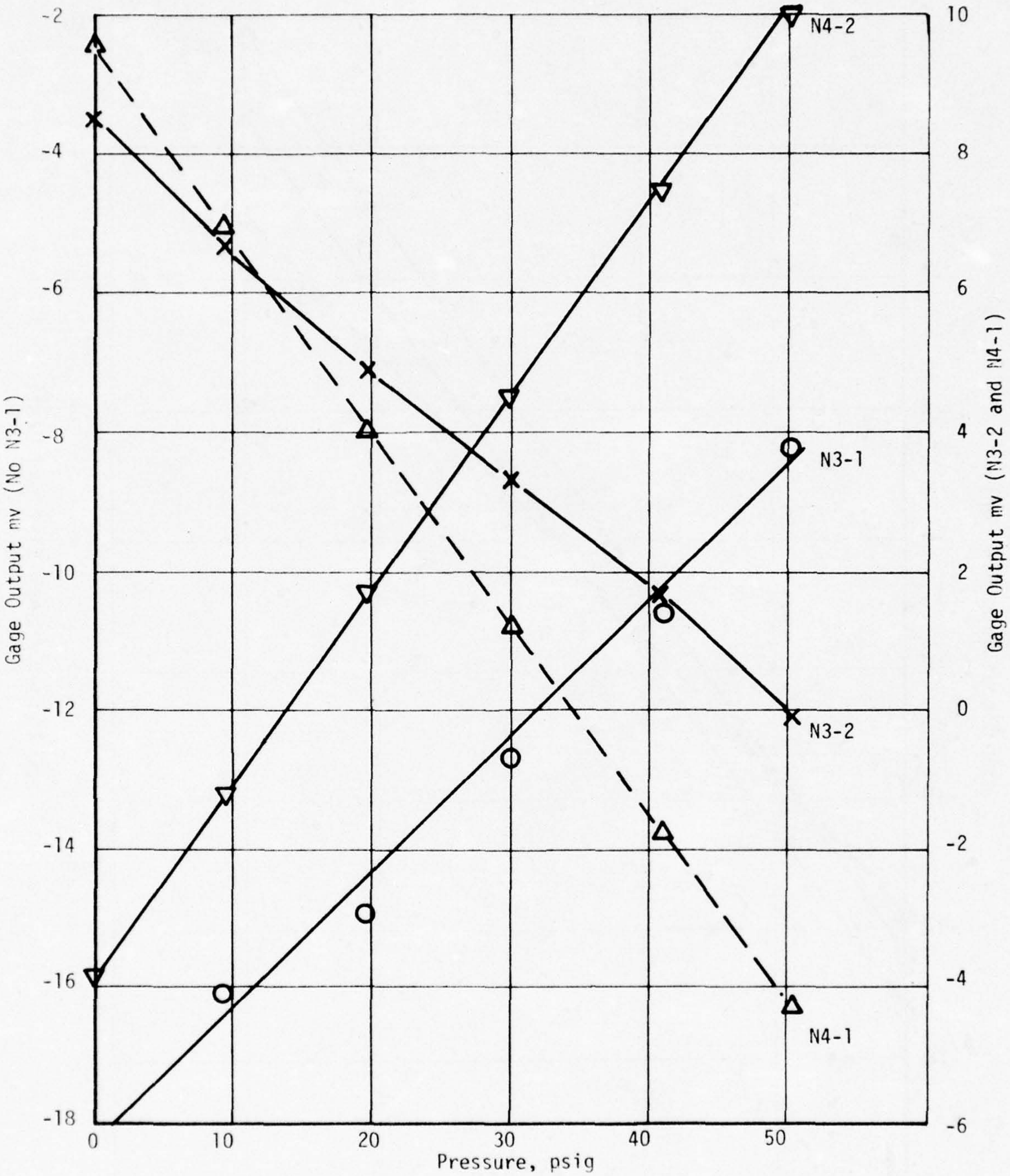


FIGURE H-7. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1: 450 PSI
NORMAL GAGES N3 AND N4

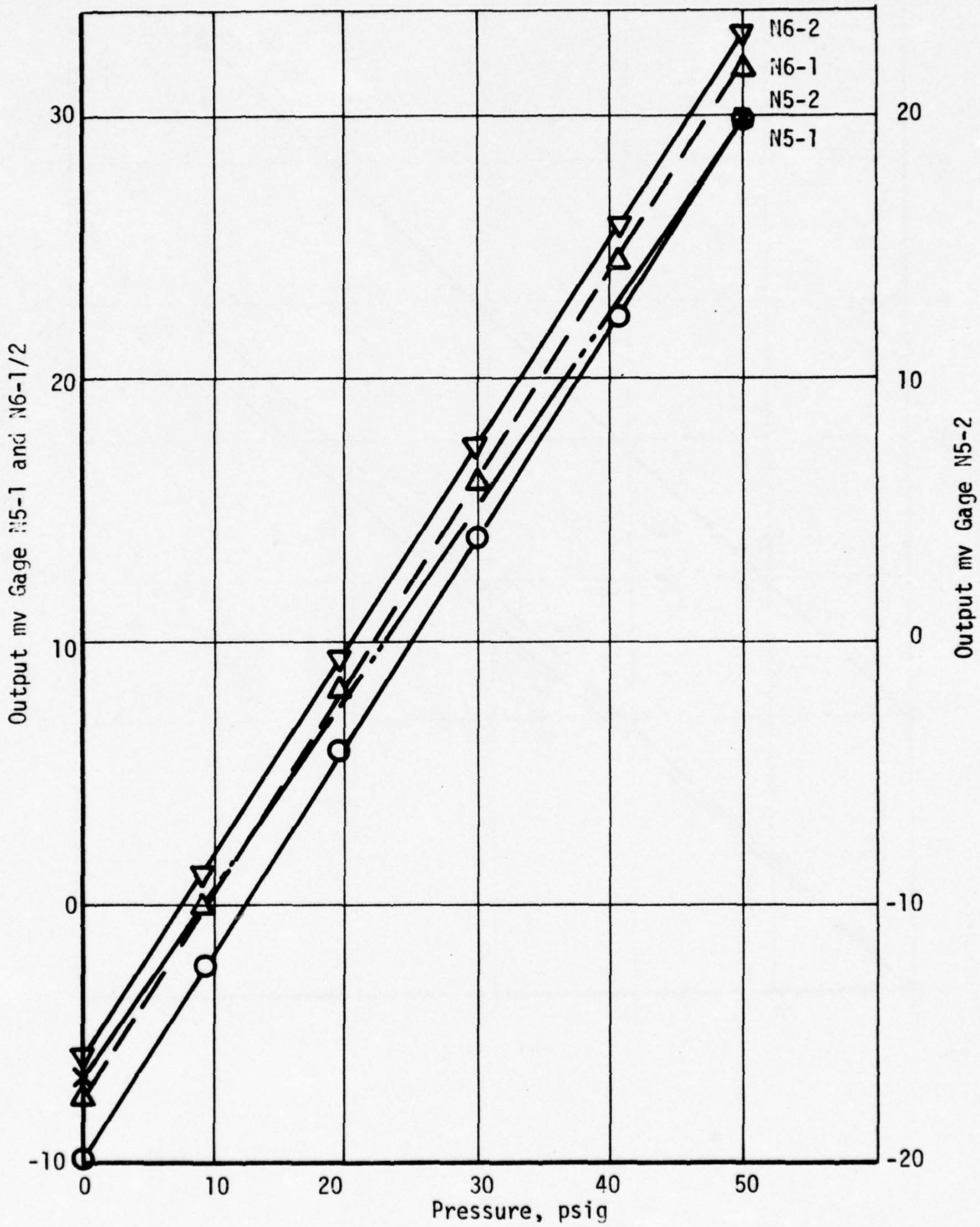


FIGURE H-8. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1
450 PSI NORMAL GAGES N5 AND N6

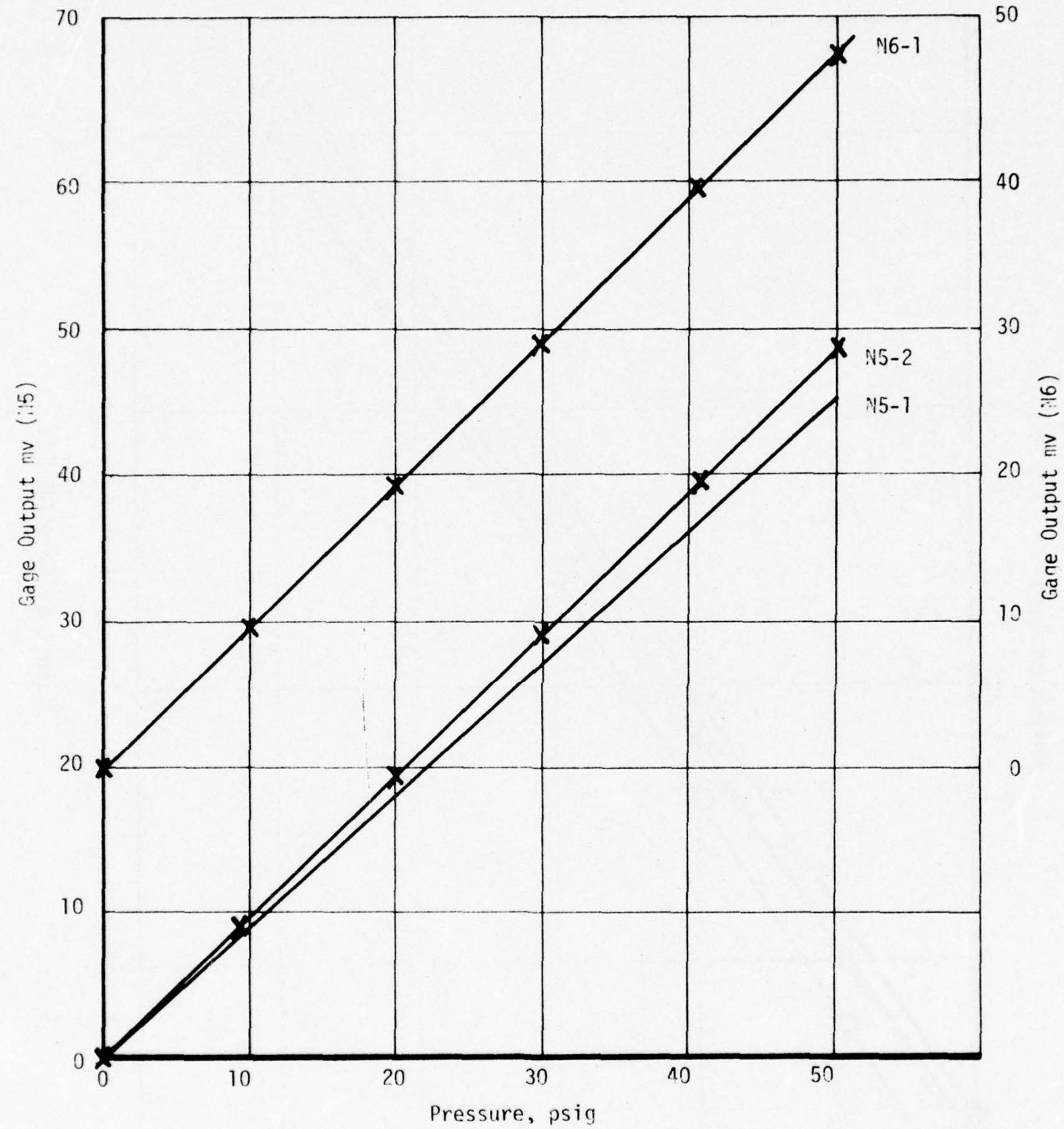


FIGURE H-9. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1
150 PSI GAGES N5 AND N6

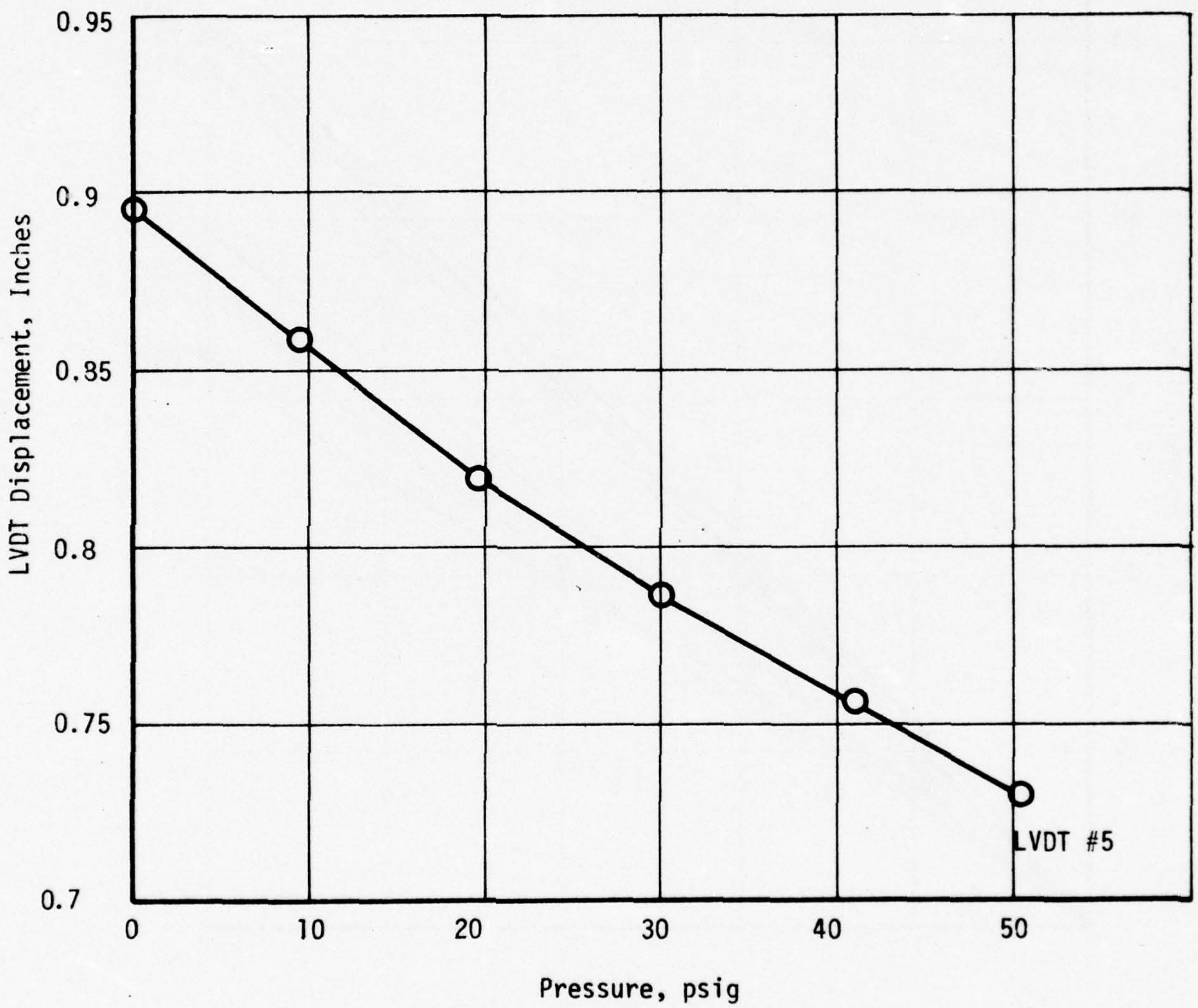


FIGURE H-10. PRESSURE TEST DATA: FULL SCALE MOTOR NO. 1 LVDT #5

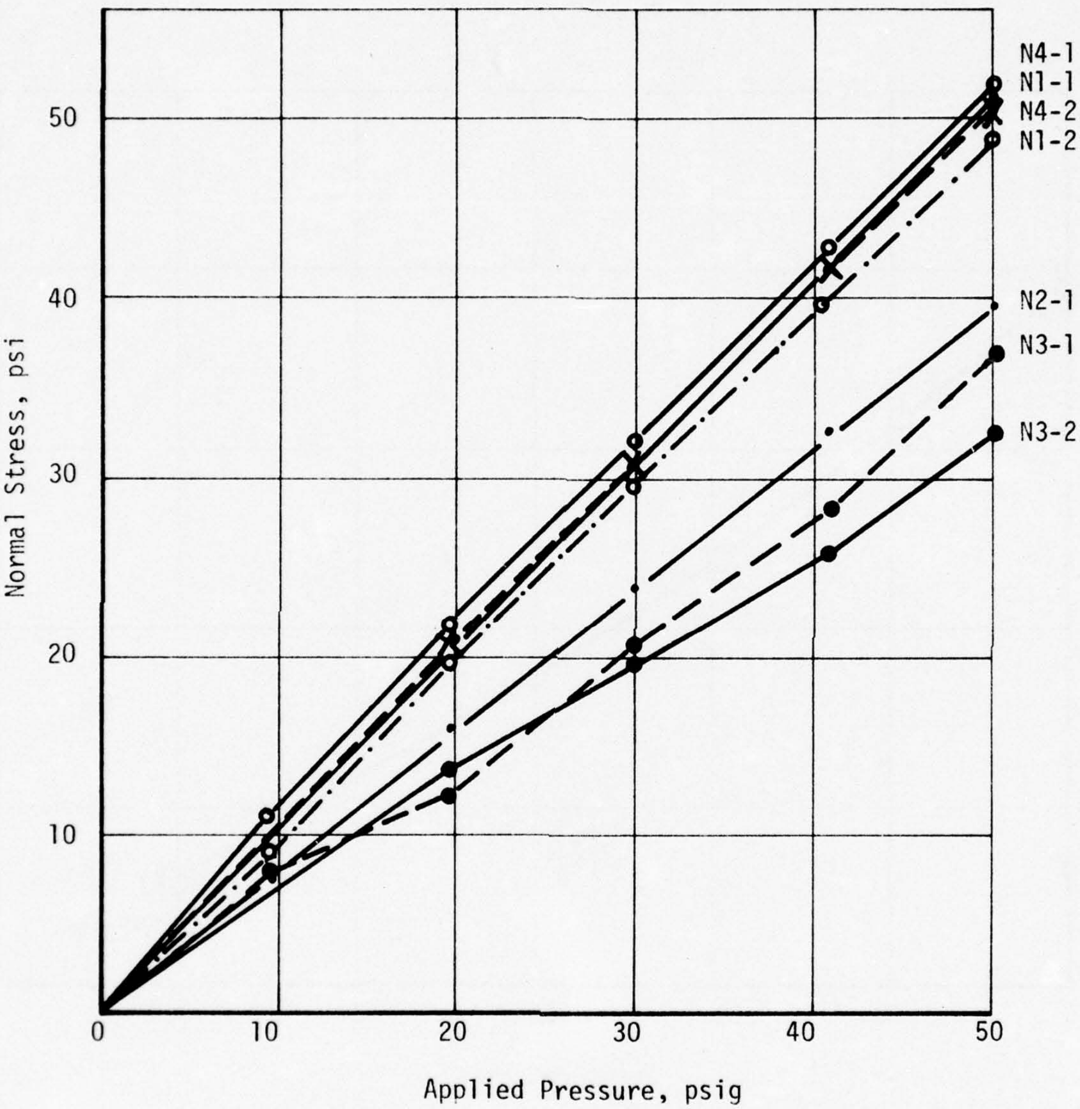


FIGURE H-11. NORMAL STRESS GAGE OUTPUT (PSI) VERSUS APPLIED PRESSURE FULL SCALE MOTOR NO. 1

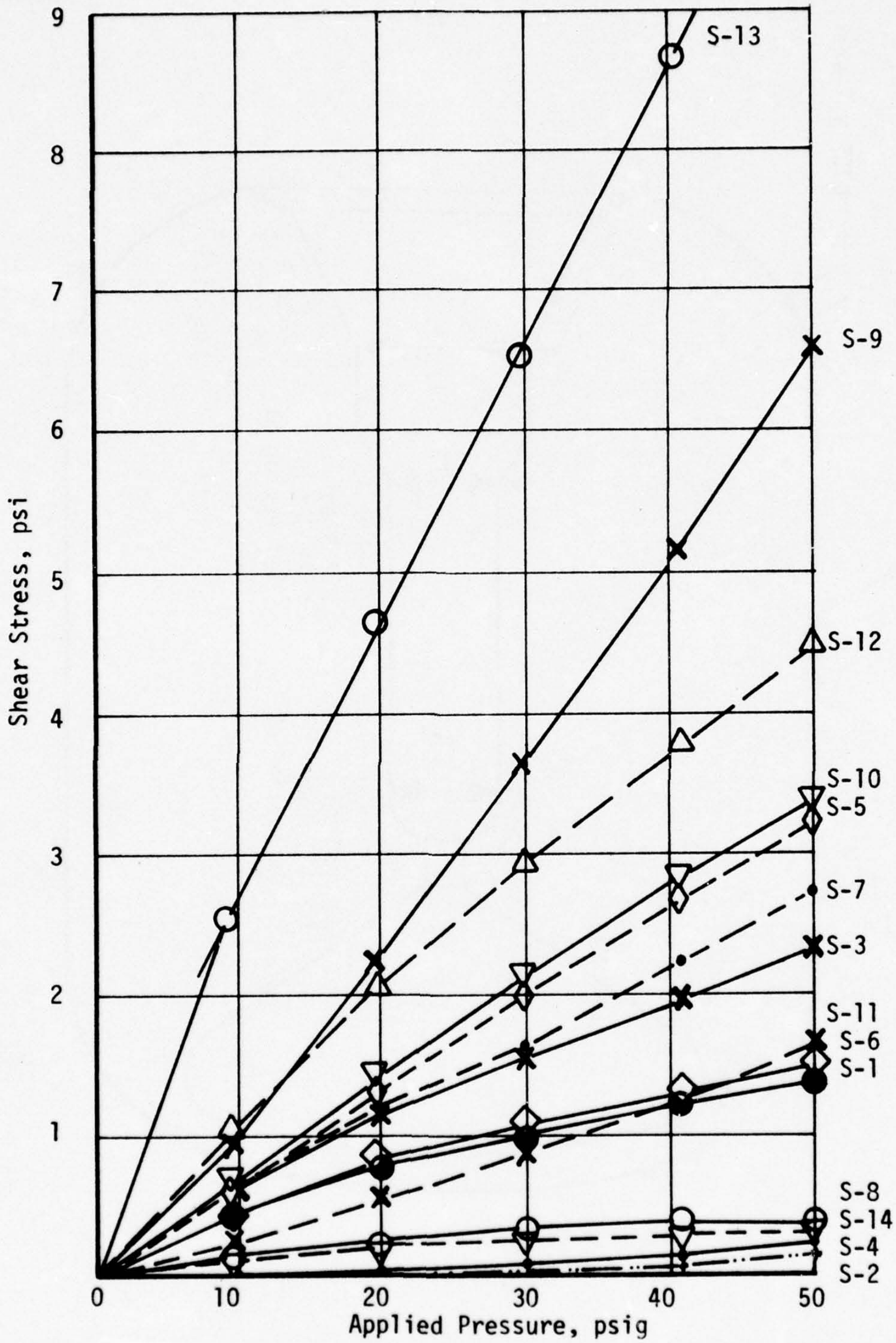


FIGURE H-12. SHEAR GAGE OUTPUT PSI VERSUS APPLIED PRESSURE FULL SCALE MOTOR NO. 1

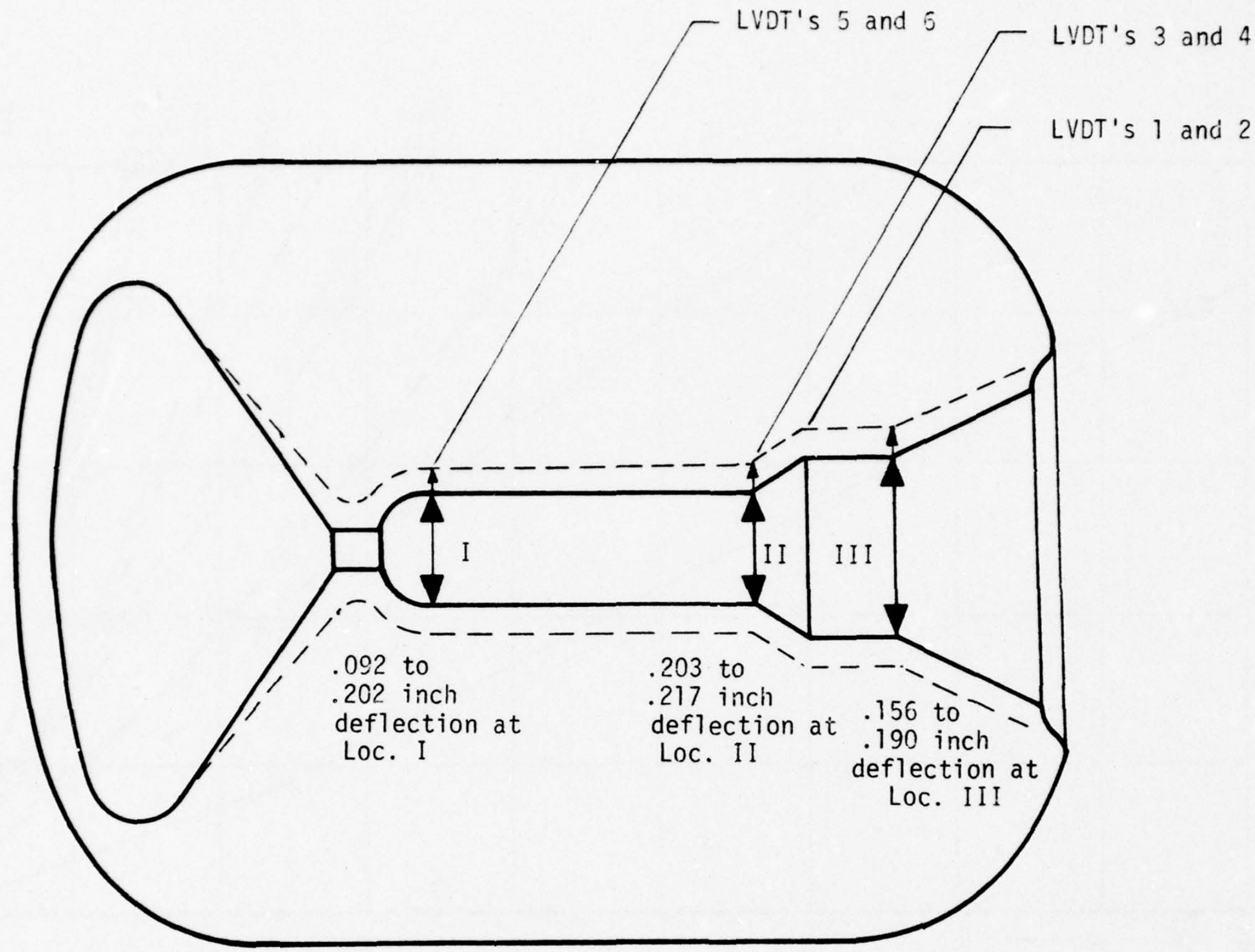


FIGURE H-13. BORE DEFLECTIONS; TEST RESULTS AT 49.45 PSIG

(T = 80 ± 5°F)

Shear Gage Sensitivity to Pressure in Motor No. 1
(Before Casting)

S-1	+0.270	S-8	-0.074
S-2	-0.050	S-9	+0.026
S-3	+0.280	S-10	+0.376
S-4	+0.150	S-11	-0.062
S-5	+0.386	S-12	-0.194
S-6	+0.012	S-13	-0.118
S-7	-0.078	S-14	-0.092

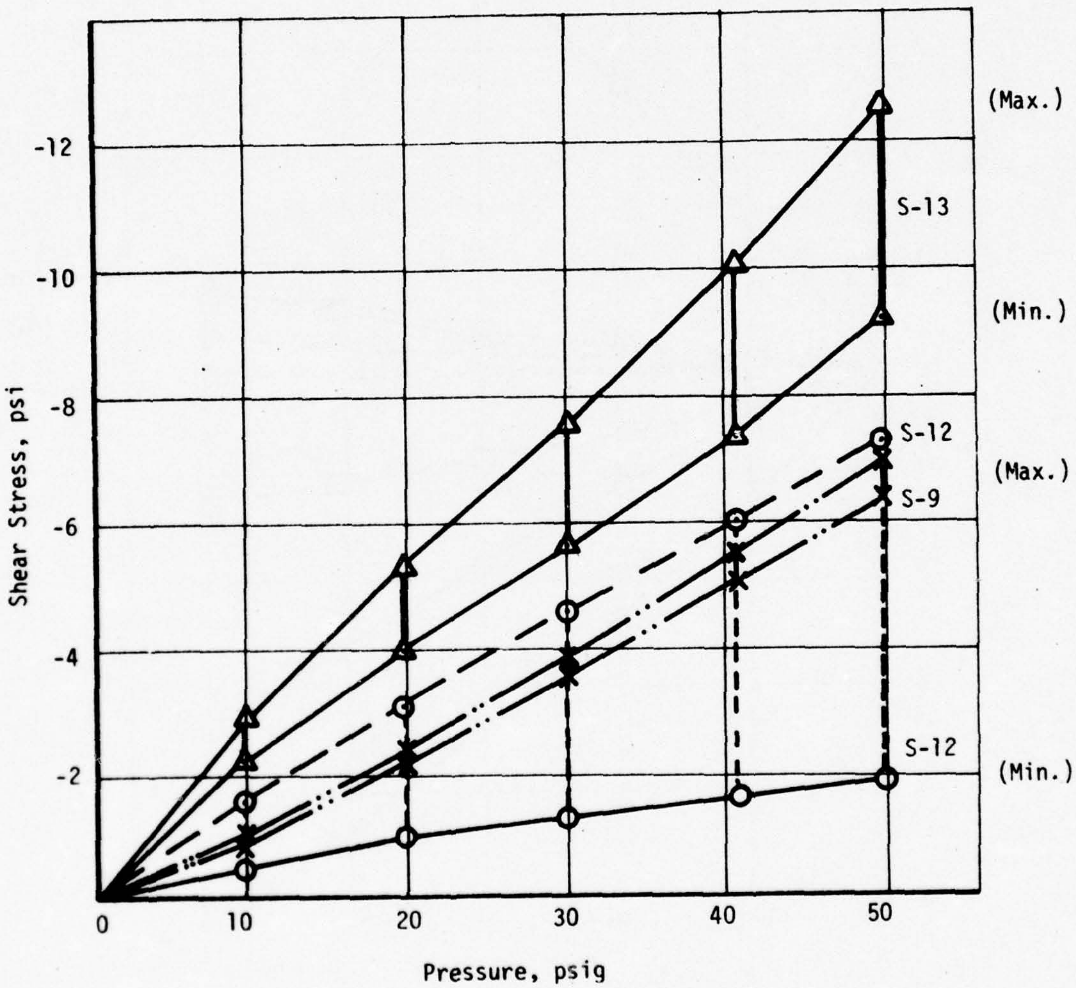


FIGURE H- 14. SHEAR STRESS DATA MOTOR NO. 1 USING PRESSURE CALIBRATION DATA FROM PRE-CAST TEST GAGES 9, 12 AND 13

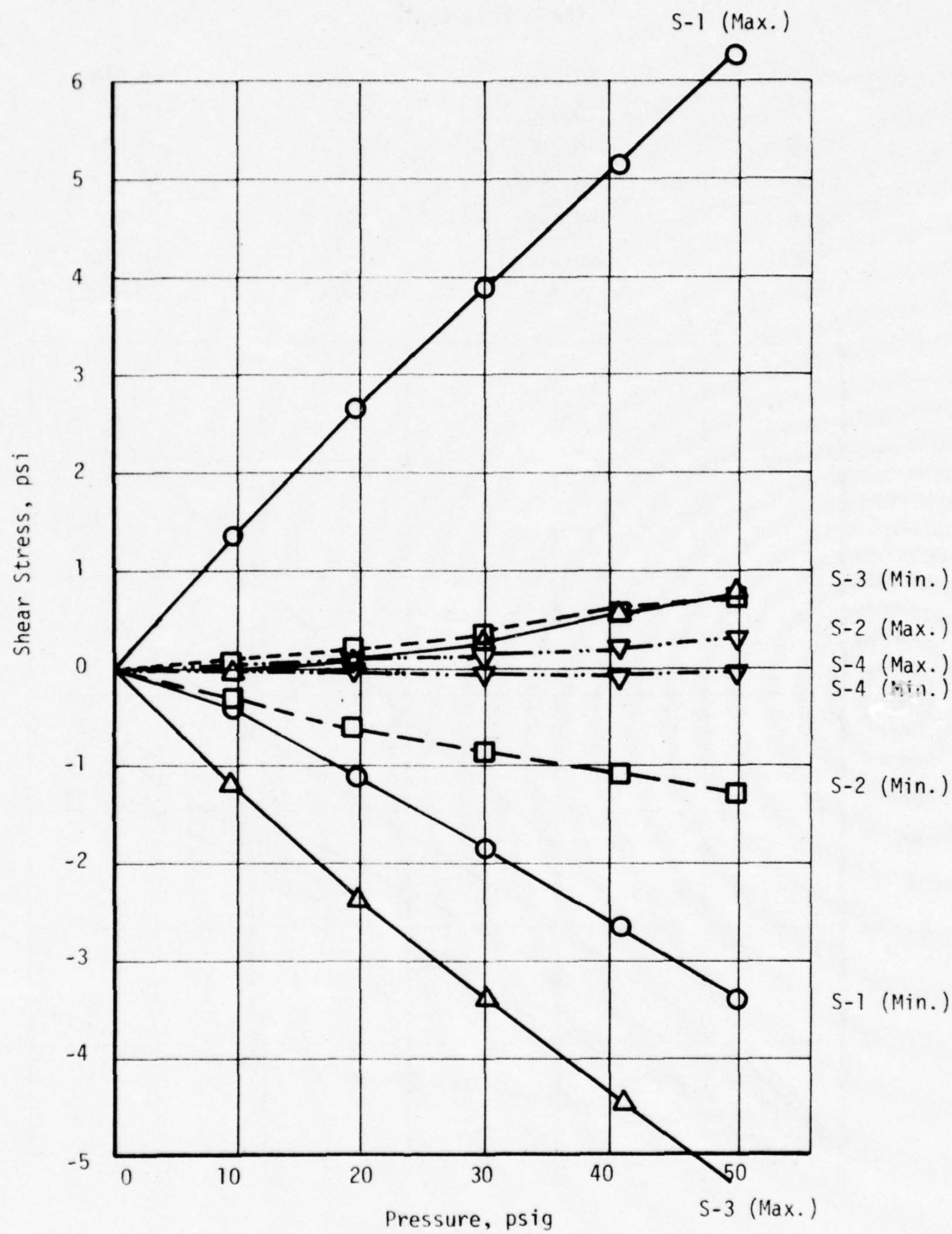


FIGURE H-15. SHEAR GAGE DATA MOTOR NO. 1 USING PRESSURE CALIBRATION DATA FROM PRE-CAST TEST GAGES 1, 2, 3 AND 4

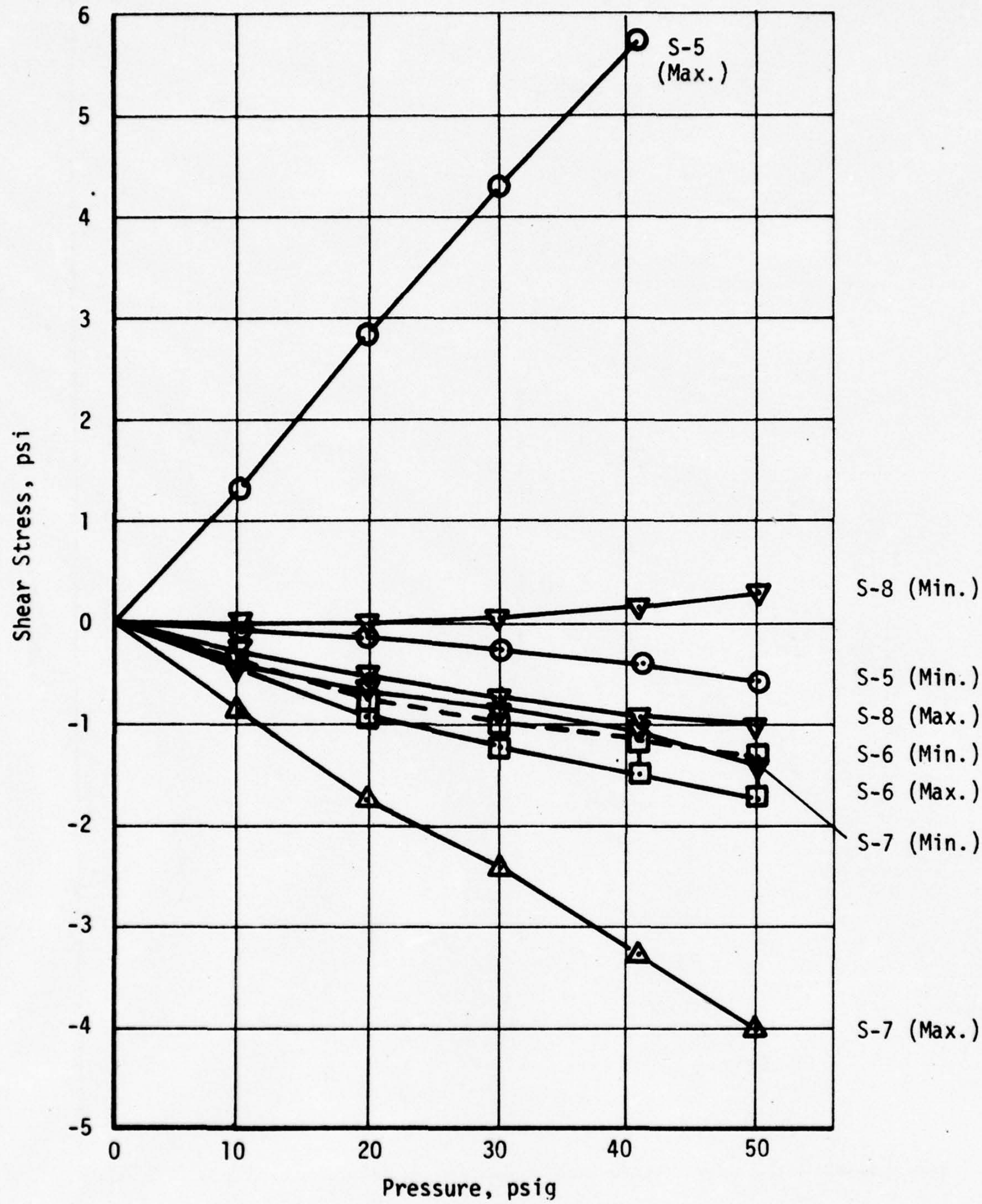


FIGURE H-16. SHEAR GAGE DATA MOTOR NO. 1 USING PRESSURE CALIBRATION DATA FROM PRE-CAST TEST GAGES 5, 6, 7 AND 8

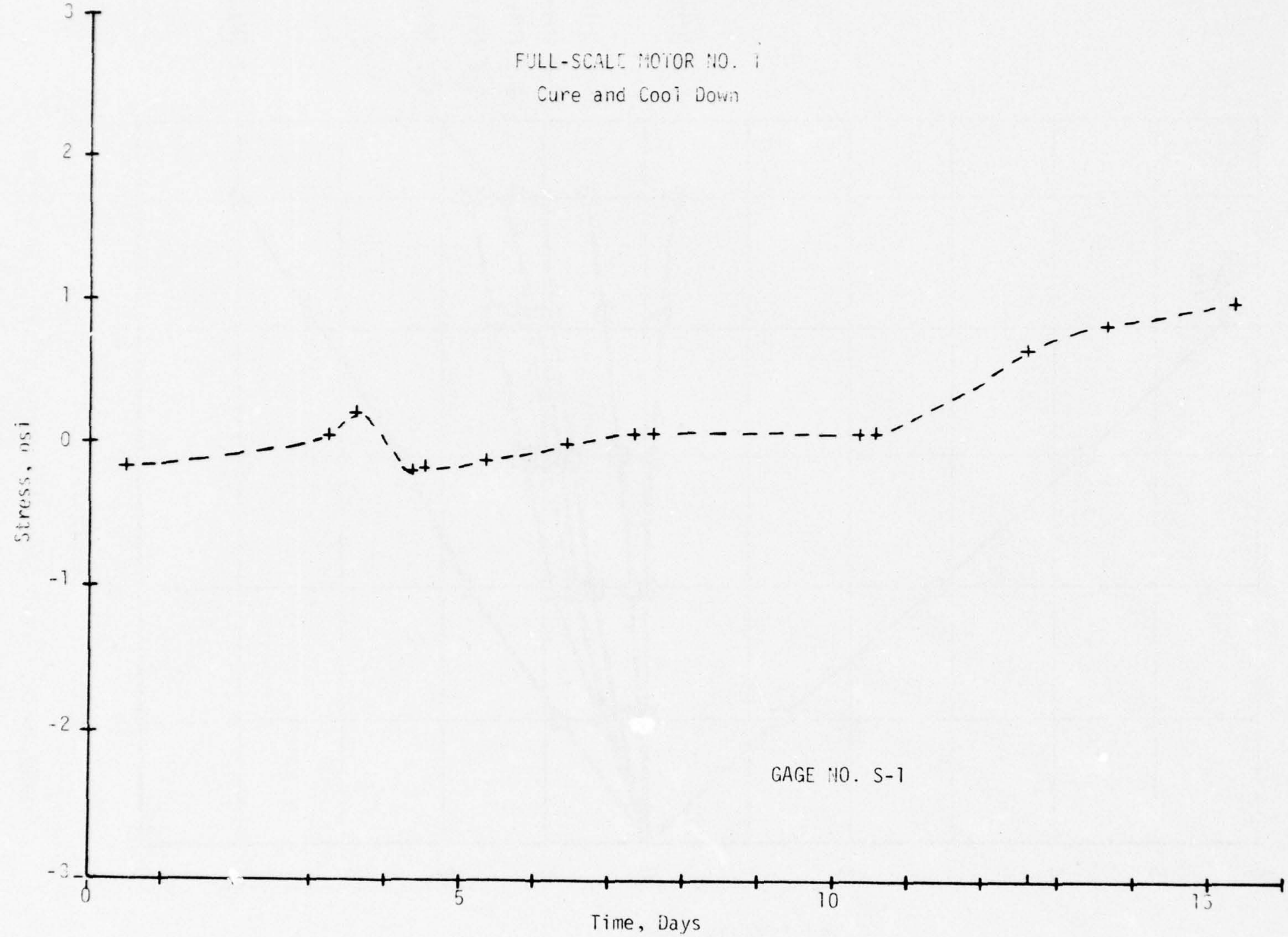


FIGURE H-17. SHEAR STRESS DATA FROM GAGE S-1; CURE AND COOLDOWN

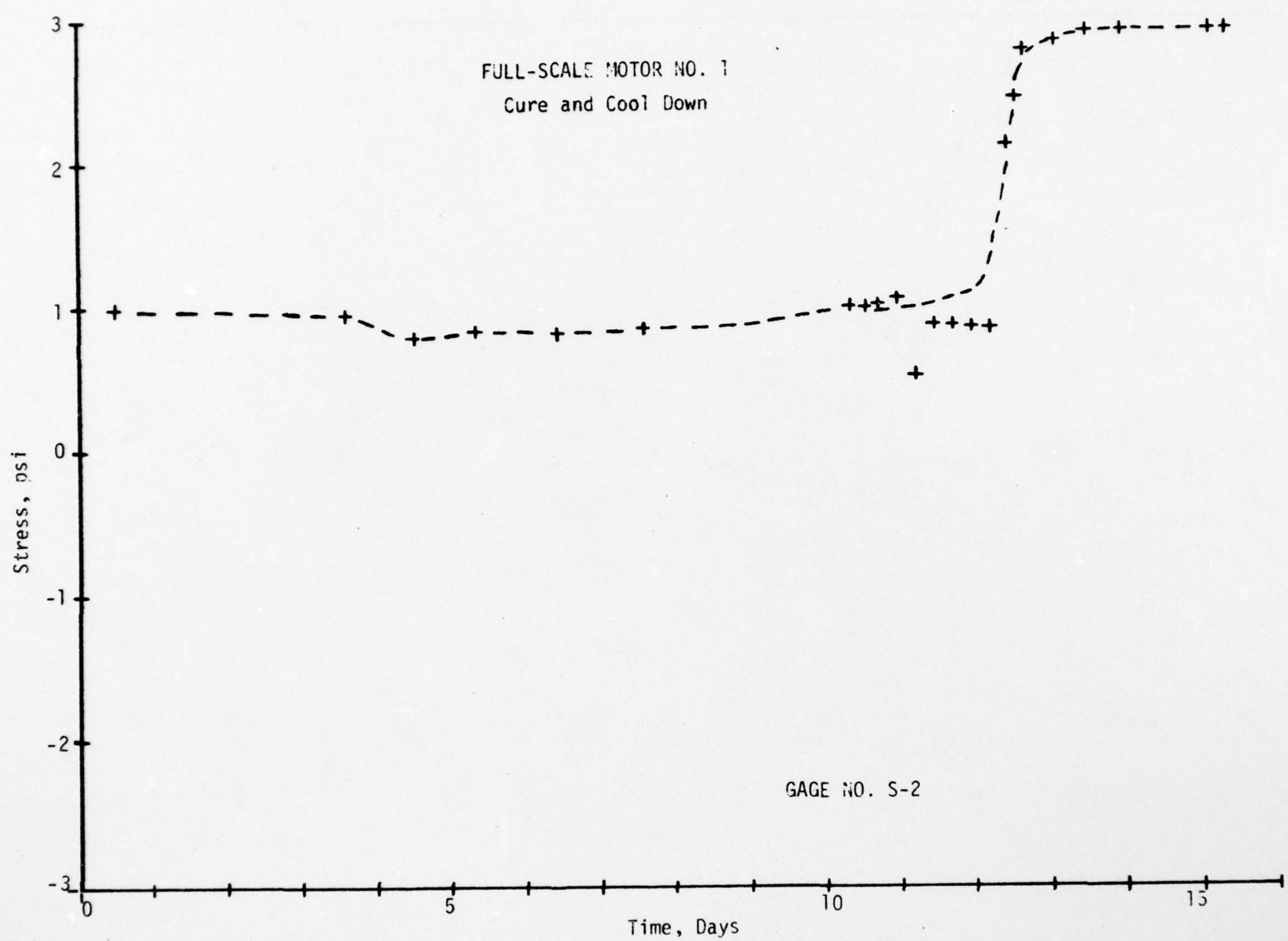


FIGURE H-18. SHEAR STRESS DATA FROM GAGE S-2; CURE AND COOLDOWN

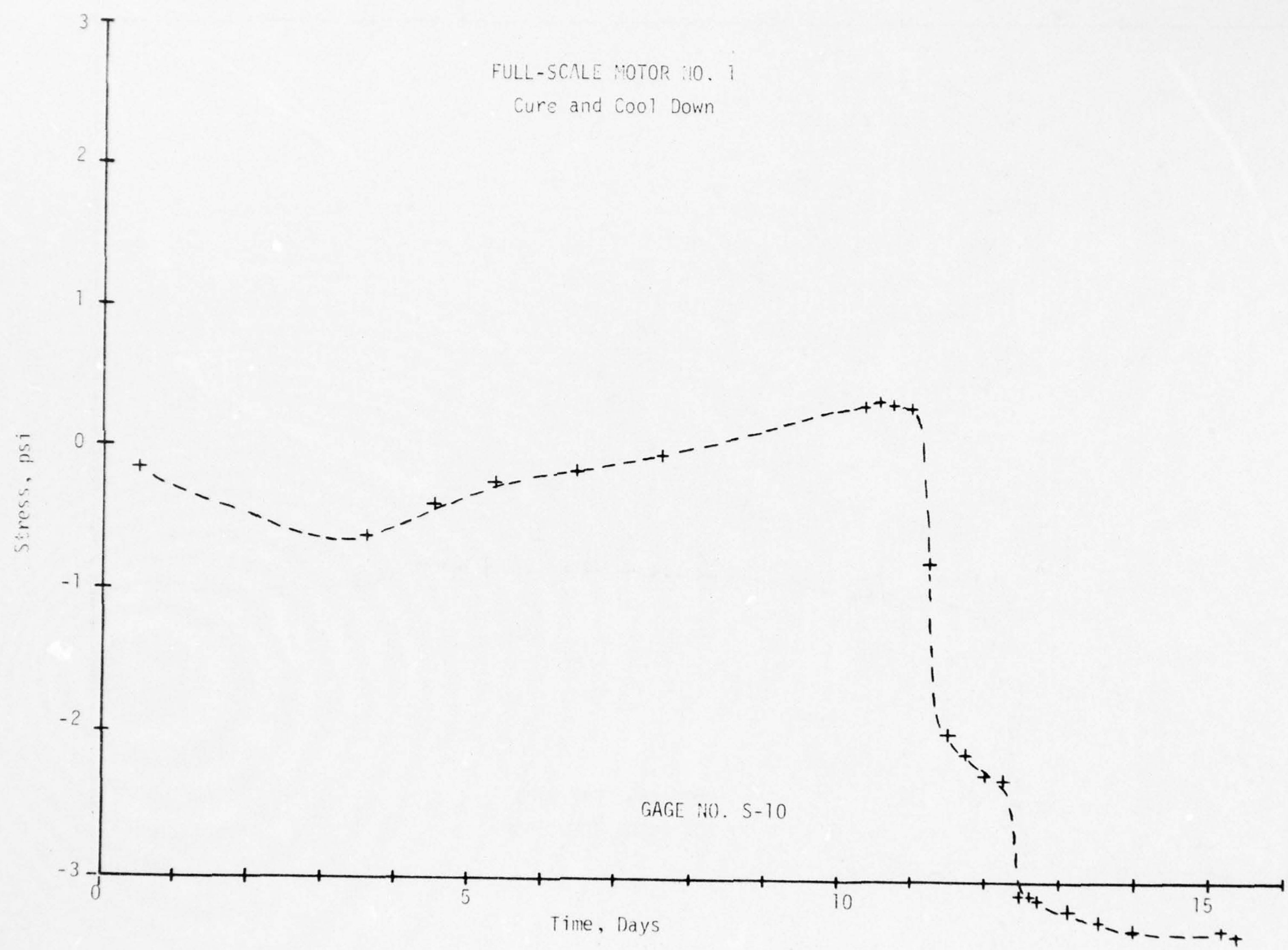


FIGURE H-19. SHEAR STRESS DATA FROM GAGE S-10; CURE AND COOLDOWN

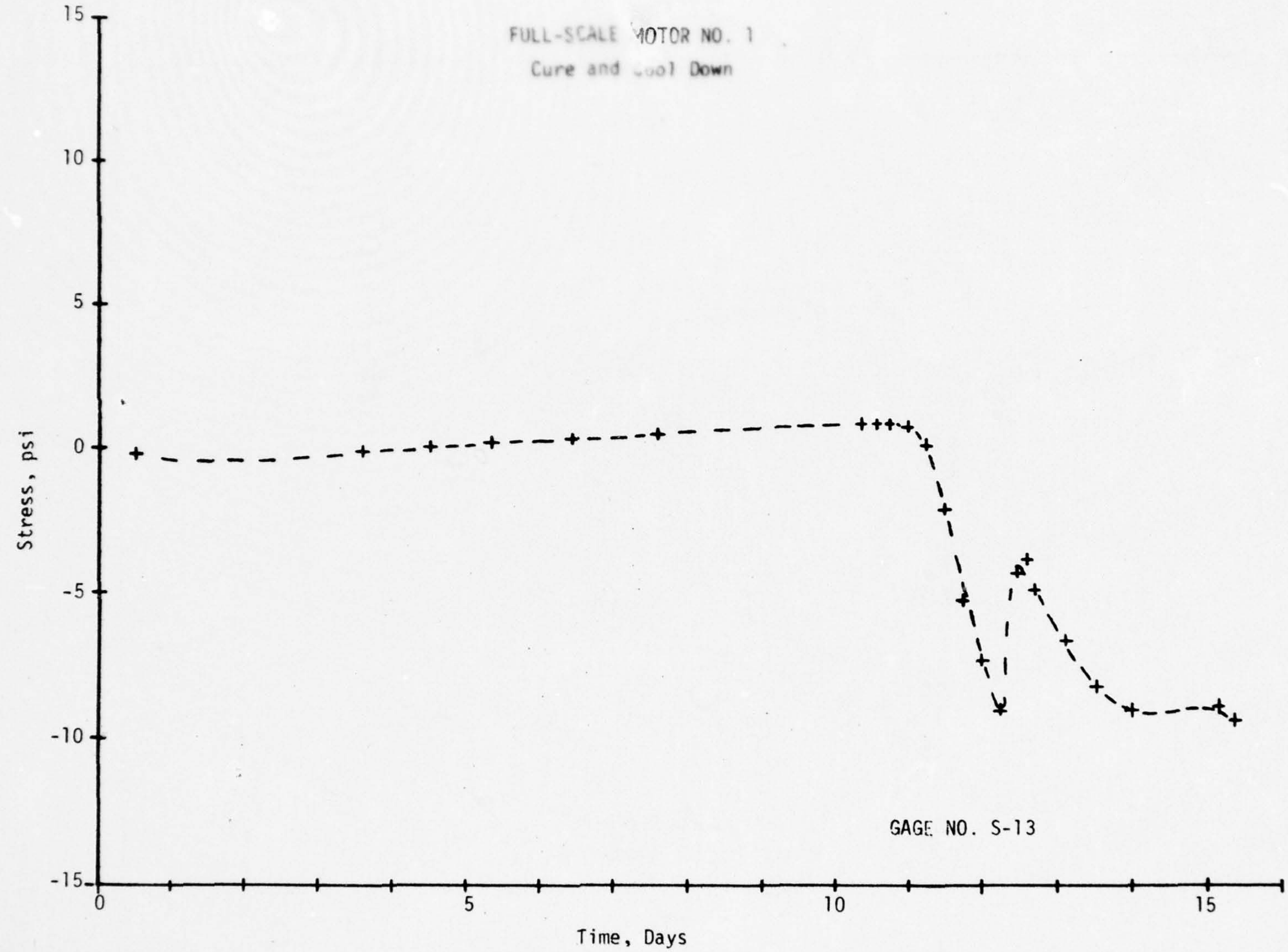


FIGURE H-20. SHEAR STRESS DATA FROM GAGE S-13; CURE AND COOLDOWN

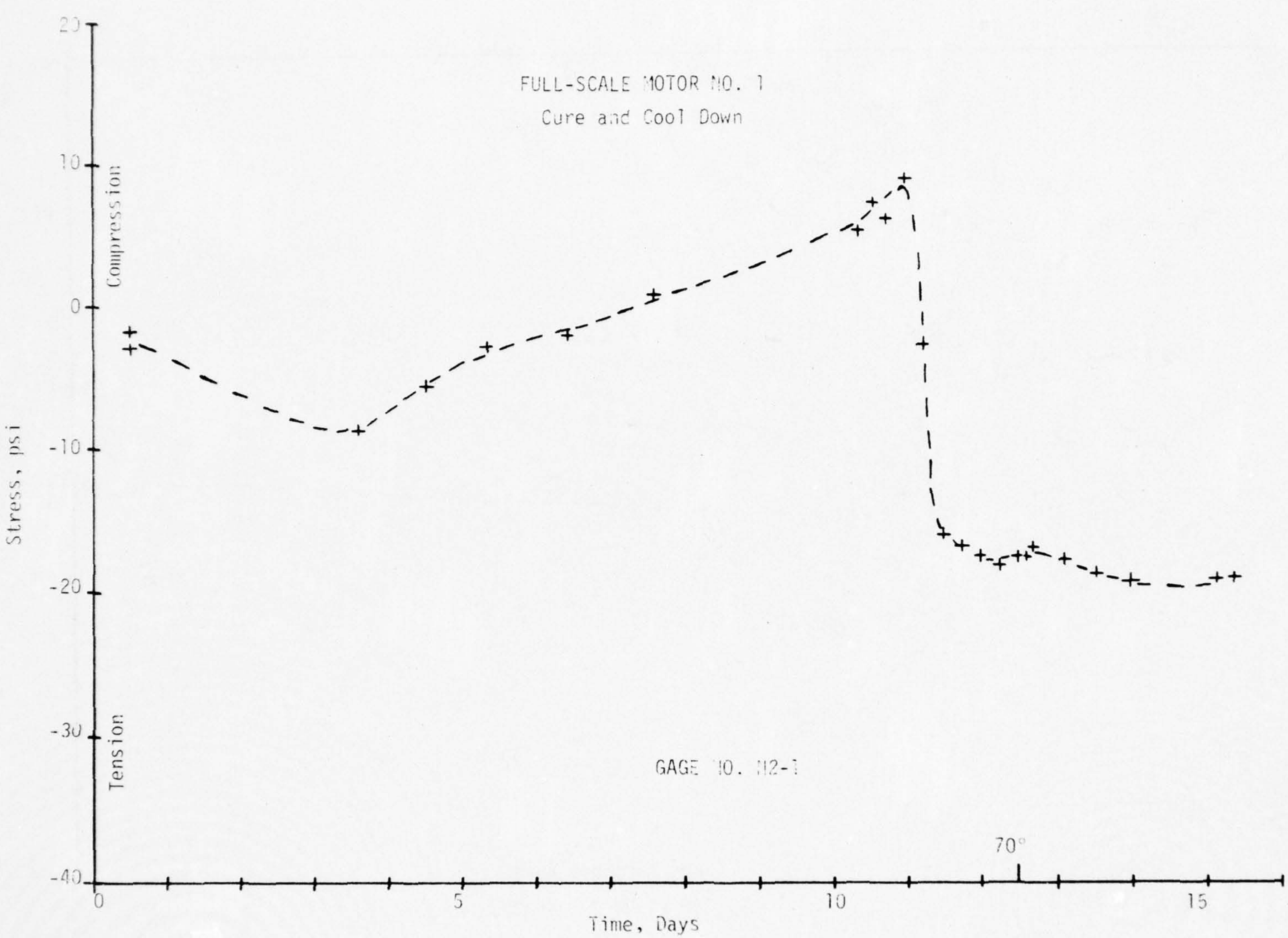


FIGURE H-21. NORMAL STRESS DATA FROM GAGE N2-1; CURE AND COOLDOWN

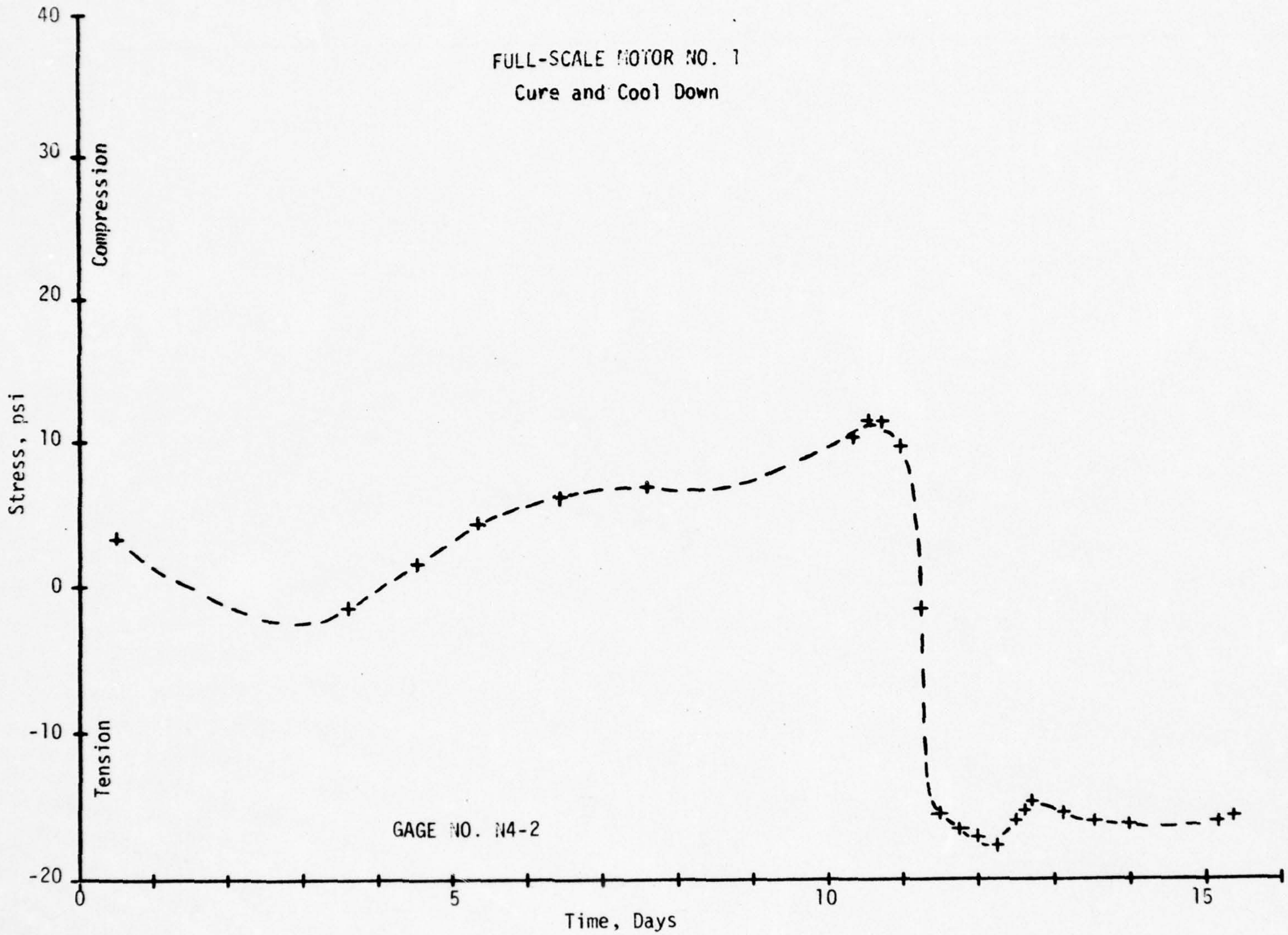


FIGURE H-22. NORMAL STRESS DATA FROM GAGE N4-2; CURE AND COOLDOWN

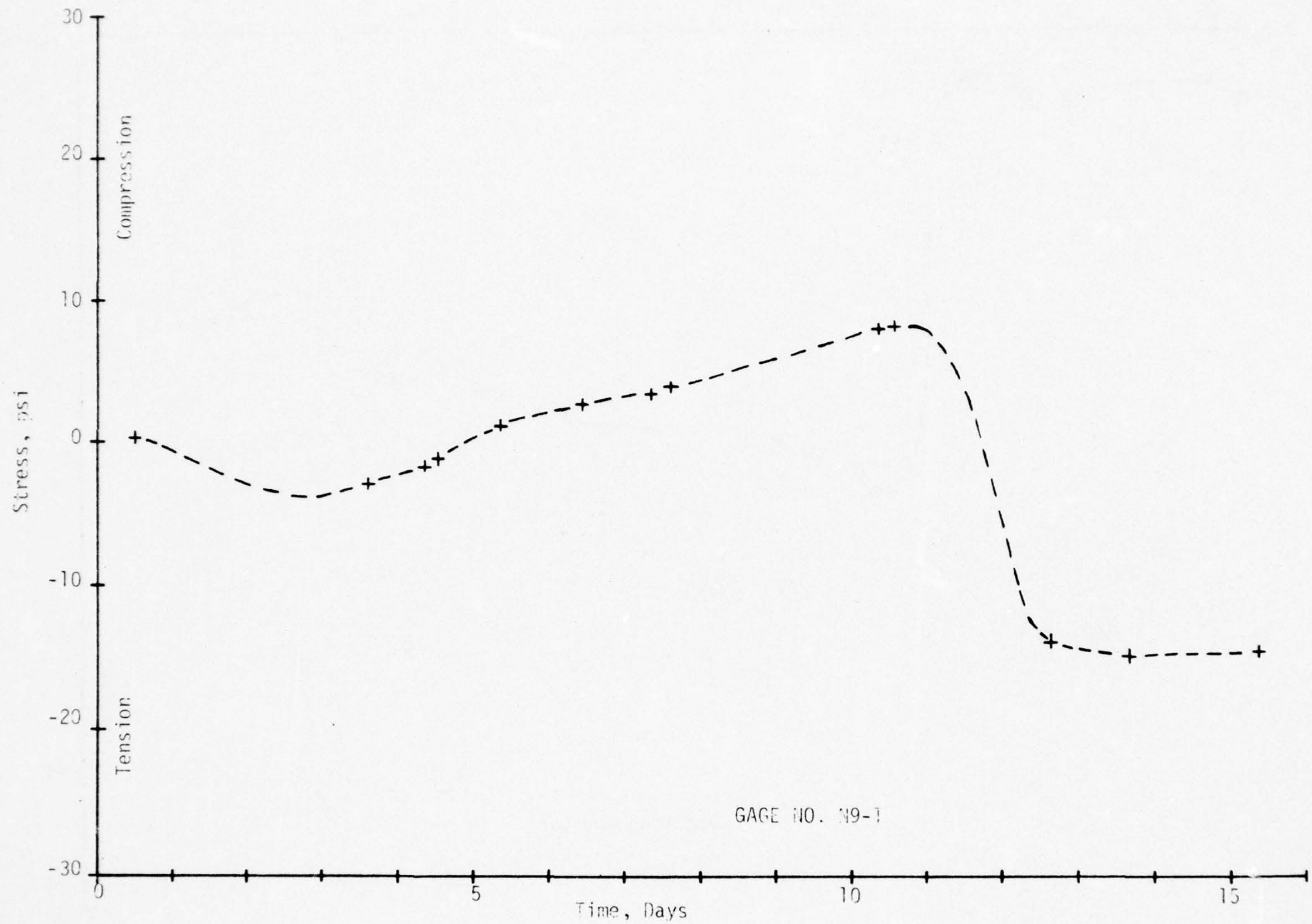


FIGURE H-23. NORMAL STRESS DATA FROM GAGE N9-1; CURE AND COOLDOWN

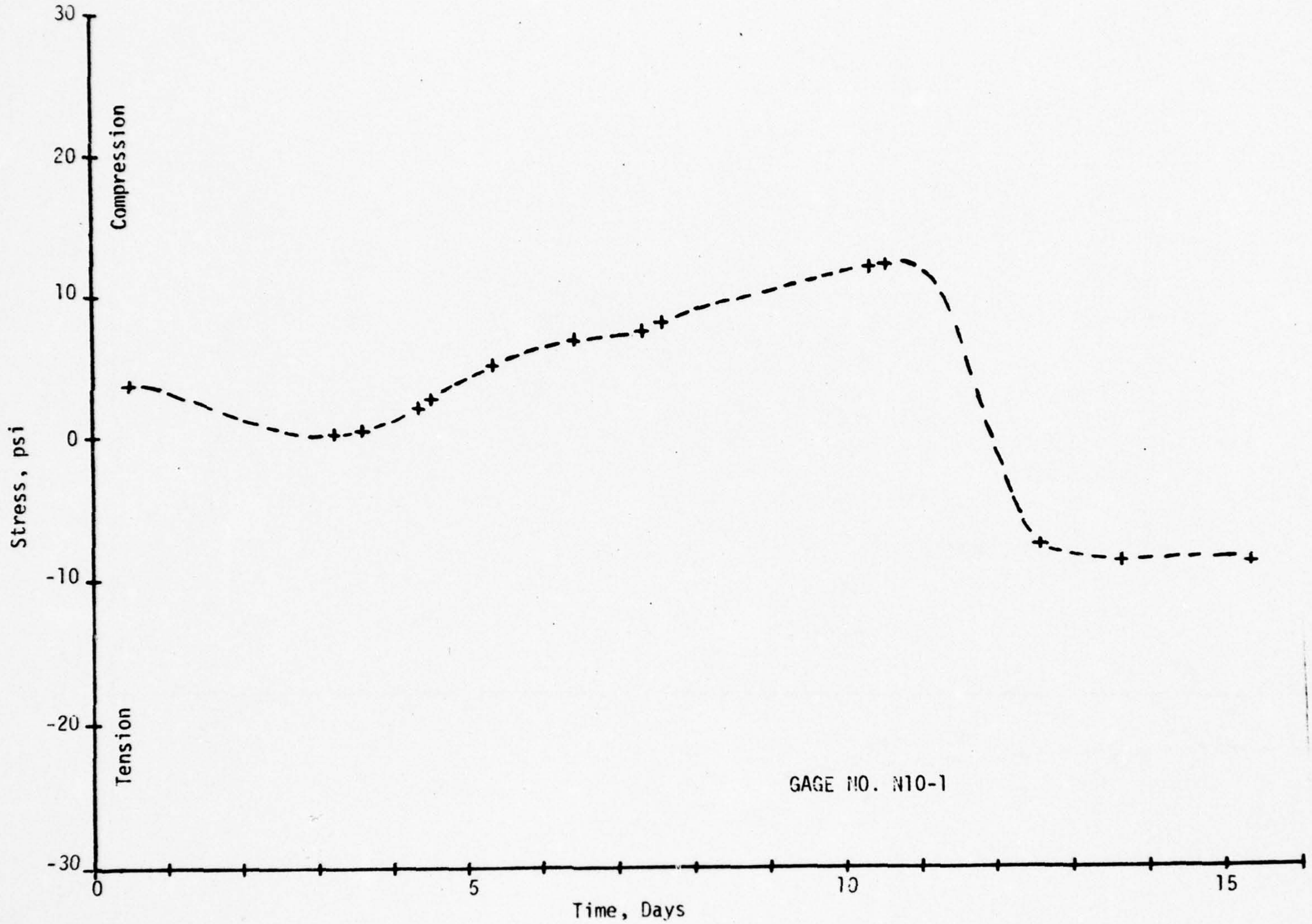


FIGURE H-24. NORMAL STRESS DATA FROM GAGE N10-1; CURE AND COOLDOWN

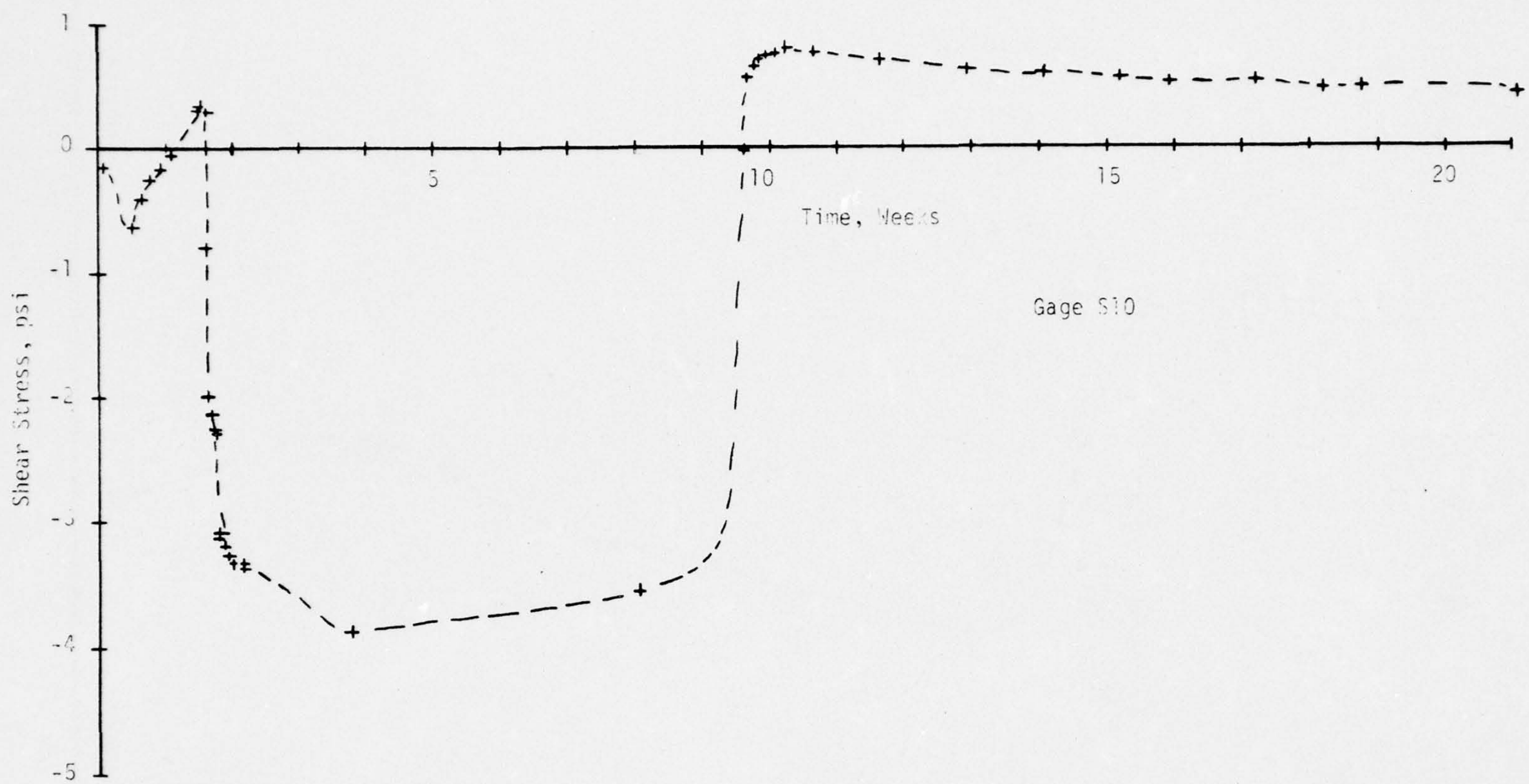


FIGURE H-25. FULL-SCALE MOTOR NO. 1, CURE AND COOLDOWN, 110°F CONDITIONING

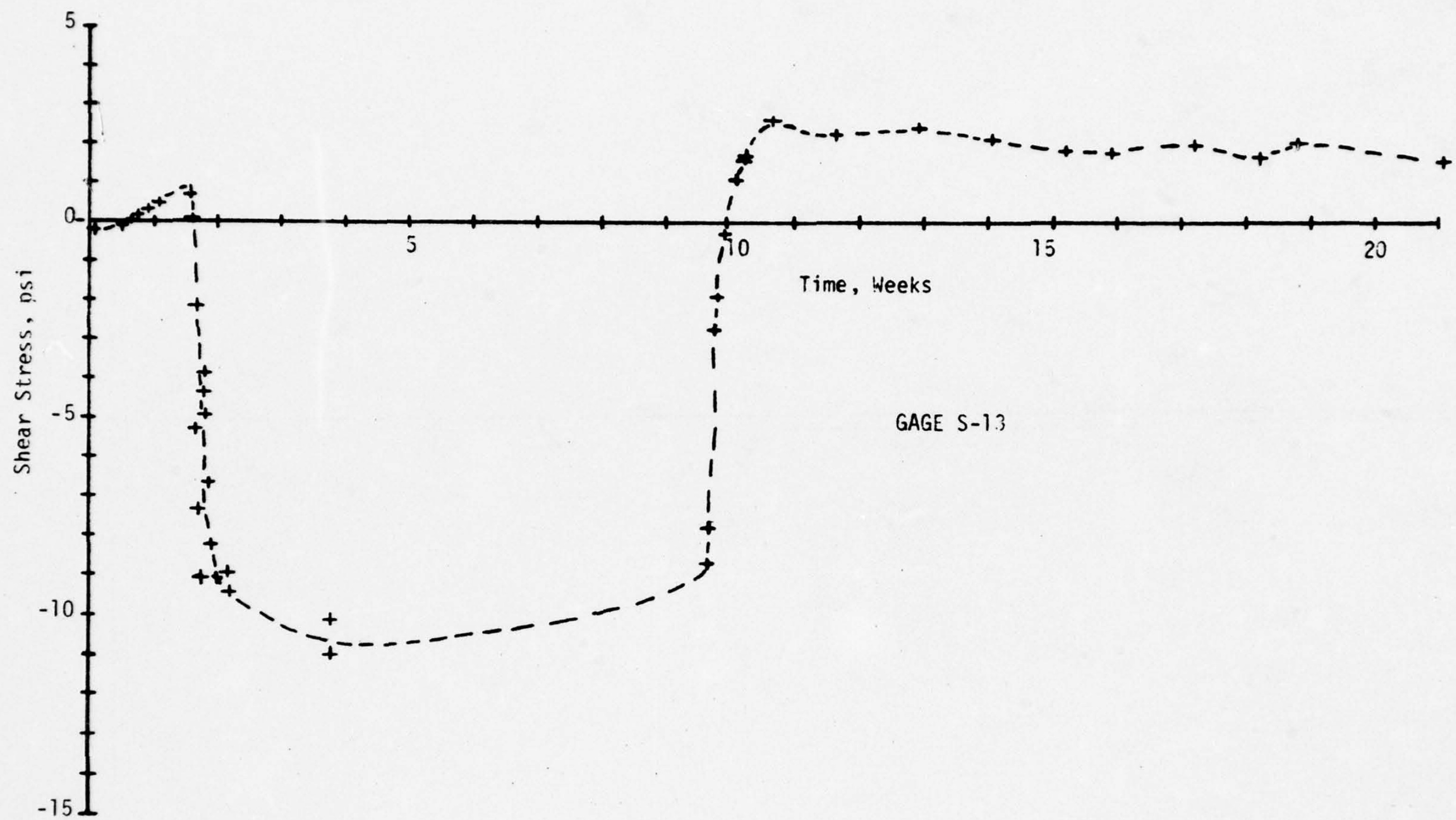


FIGURE H-26. FULL-SCALE MOTOR NO. 1, CURE AND COOLDOWN, 110°F CONDITIONING

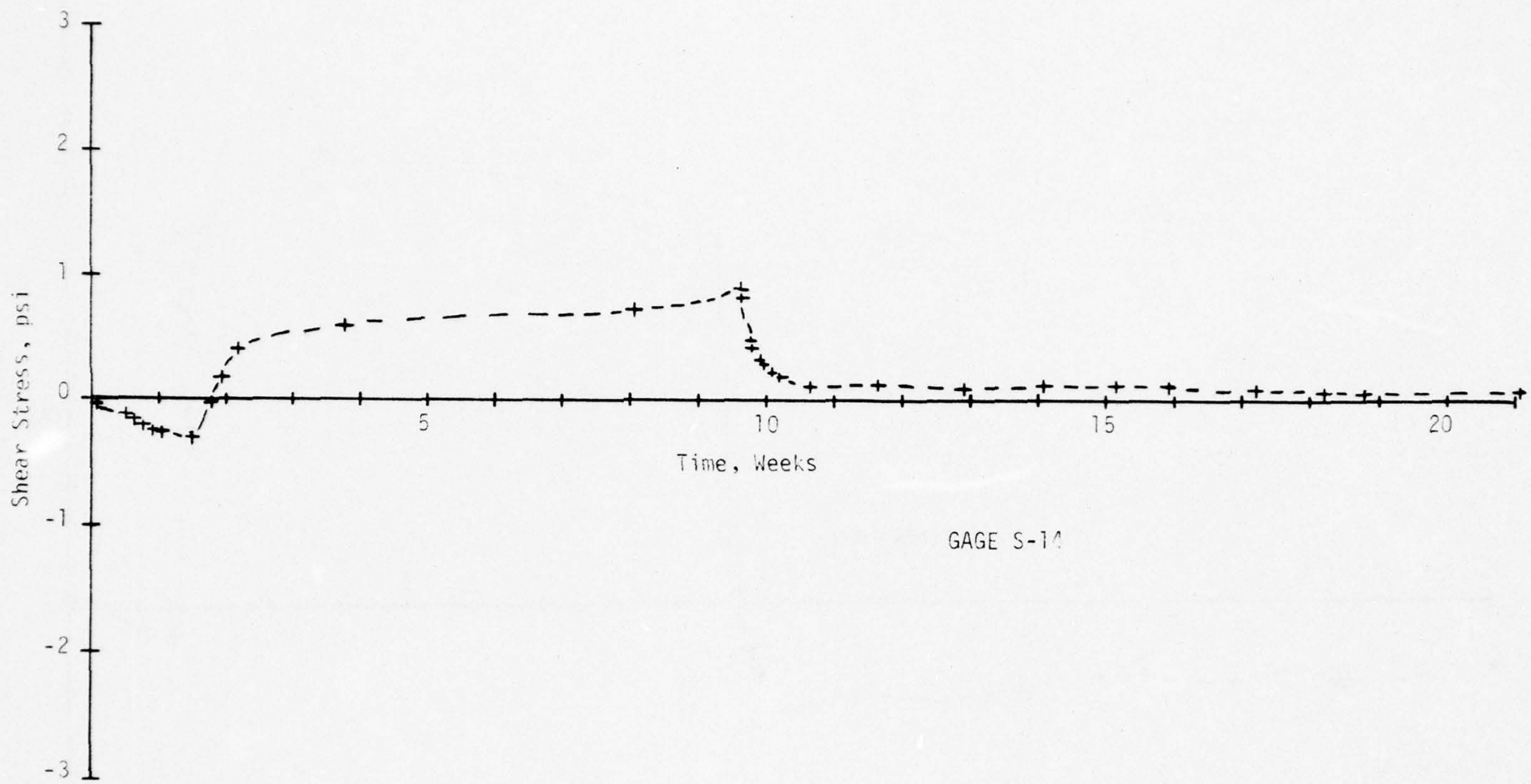


FIGURE H-27. FULL-SCALE MOTOR NO. 1, CURE AND COOLDOWN, 110°F CONDITIONING

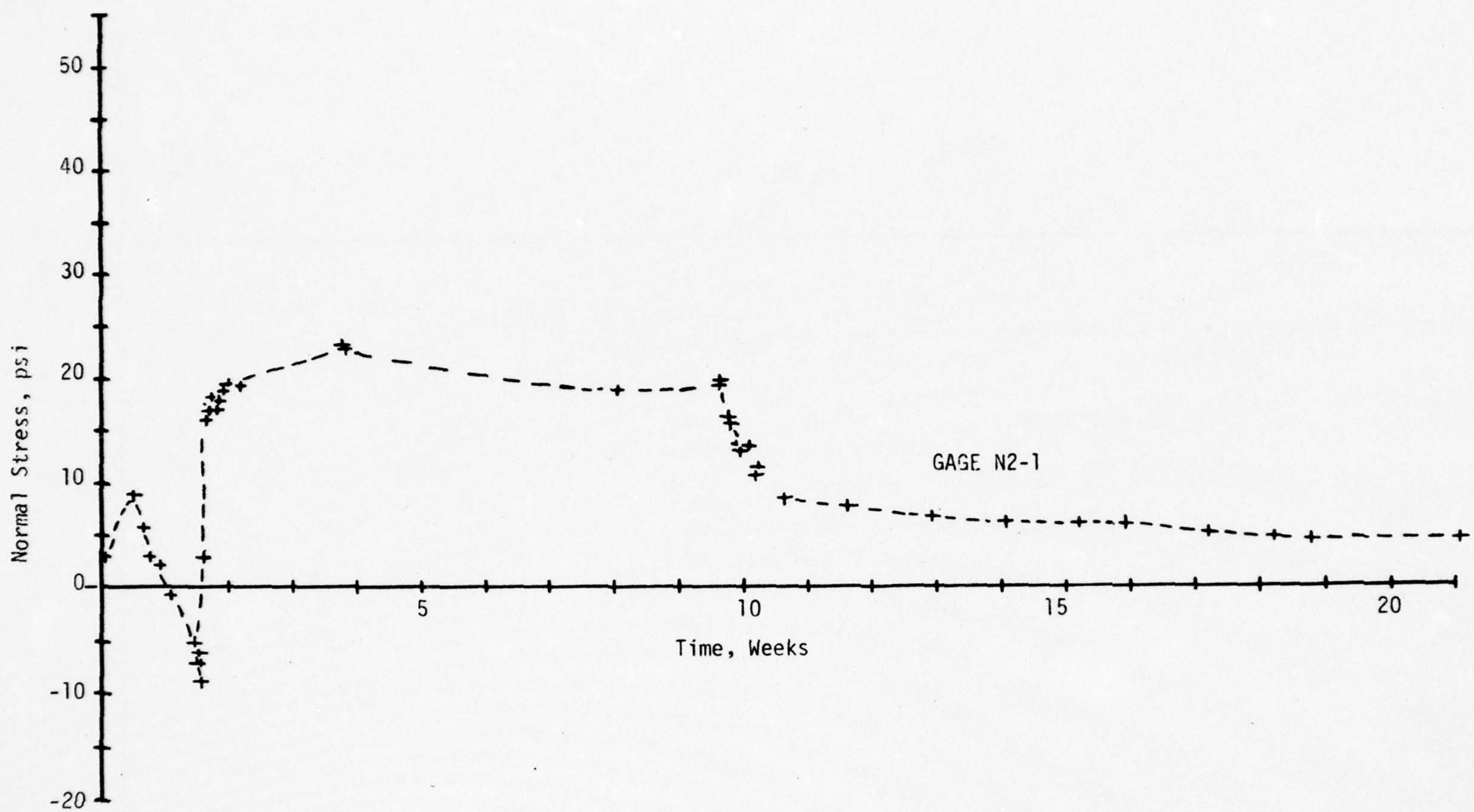


FIGURE H-28. FULL-SCALE MOTOR NO. 1, CURE AND COOLDOWN, 110°F CONDITIONING

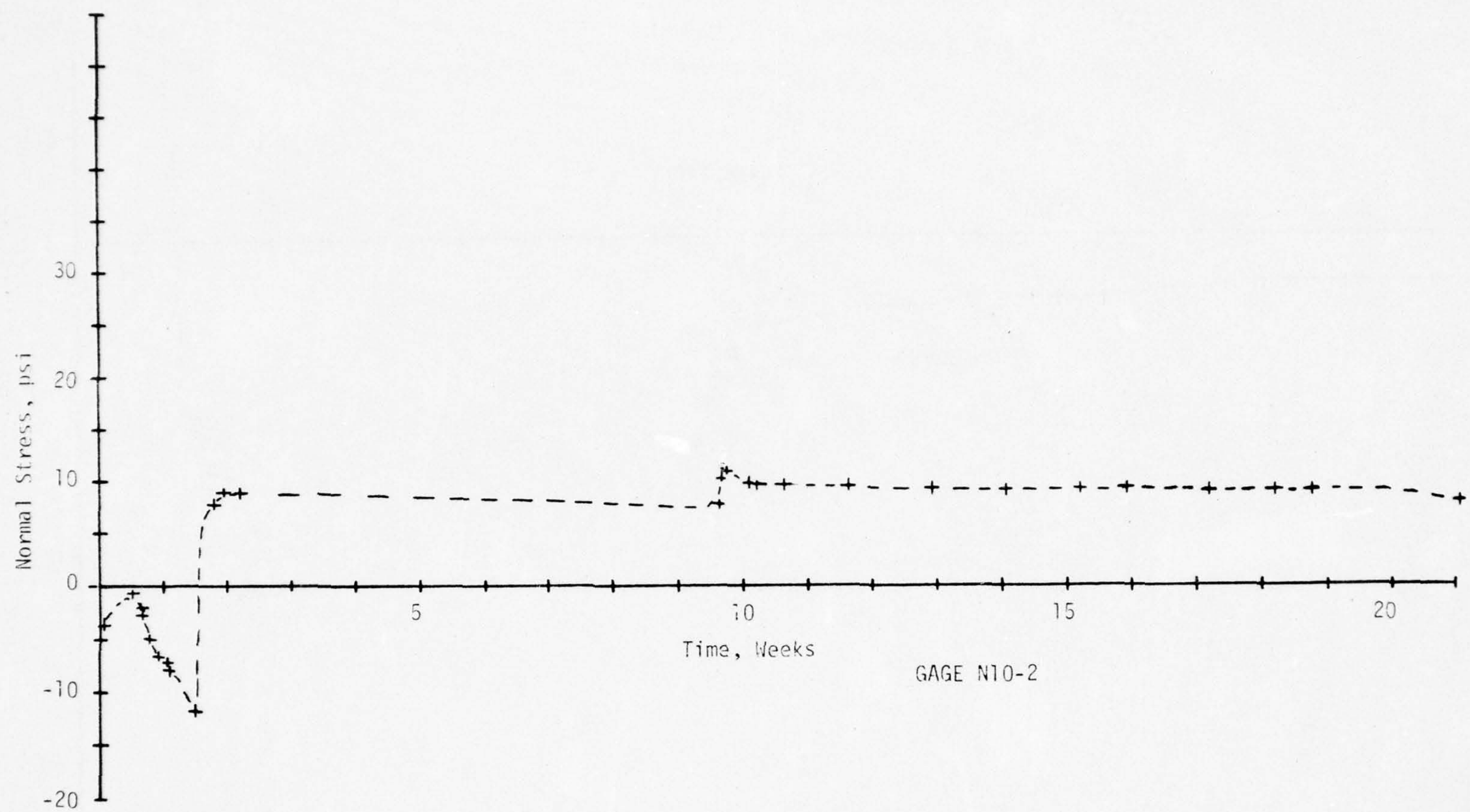


FIGURE H-29. FULL-SCALE MOTOR NO. 1, CURE AND COOLDOWN, 110°F CONDITIONING

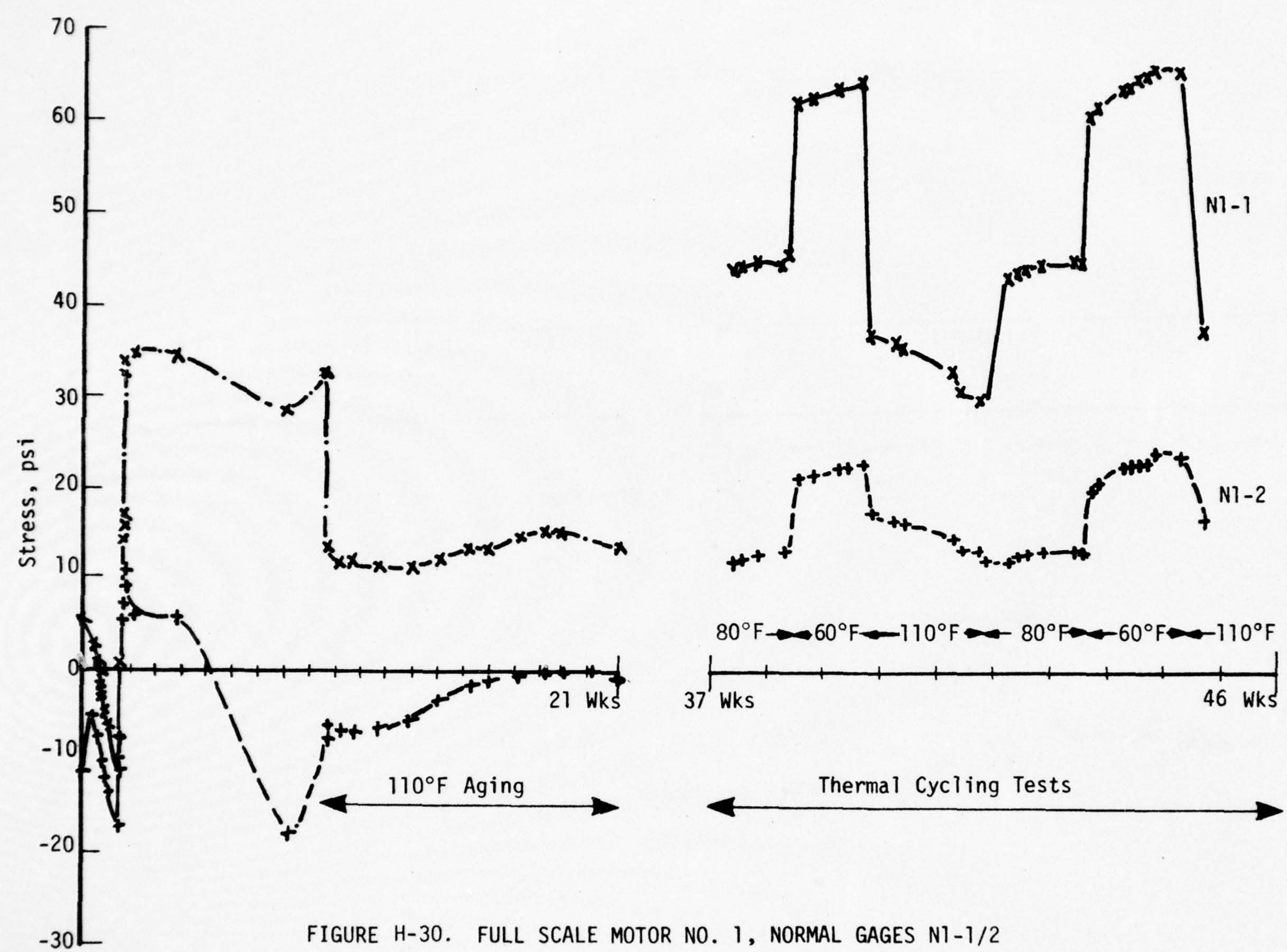


FIGURE H-30. FULL SCALE MOTOR NO. 1, NORMAL GAGES N1-1/2

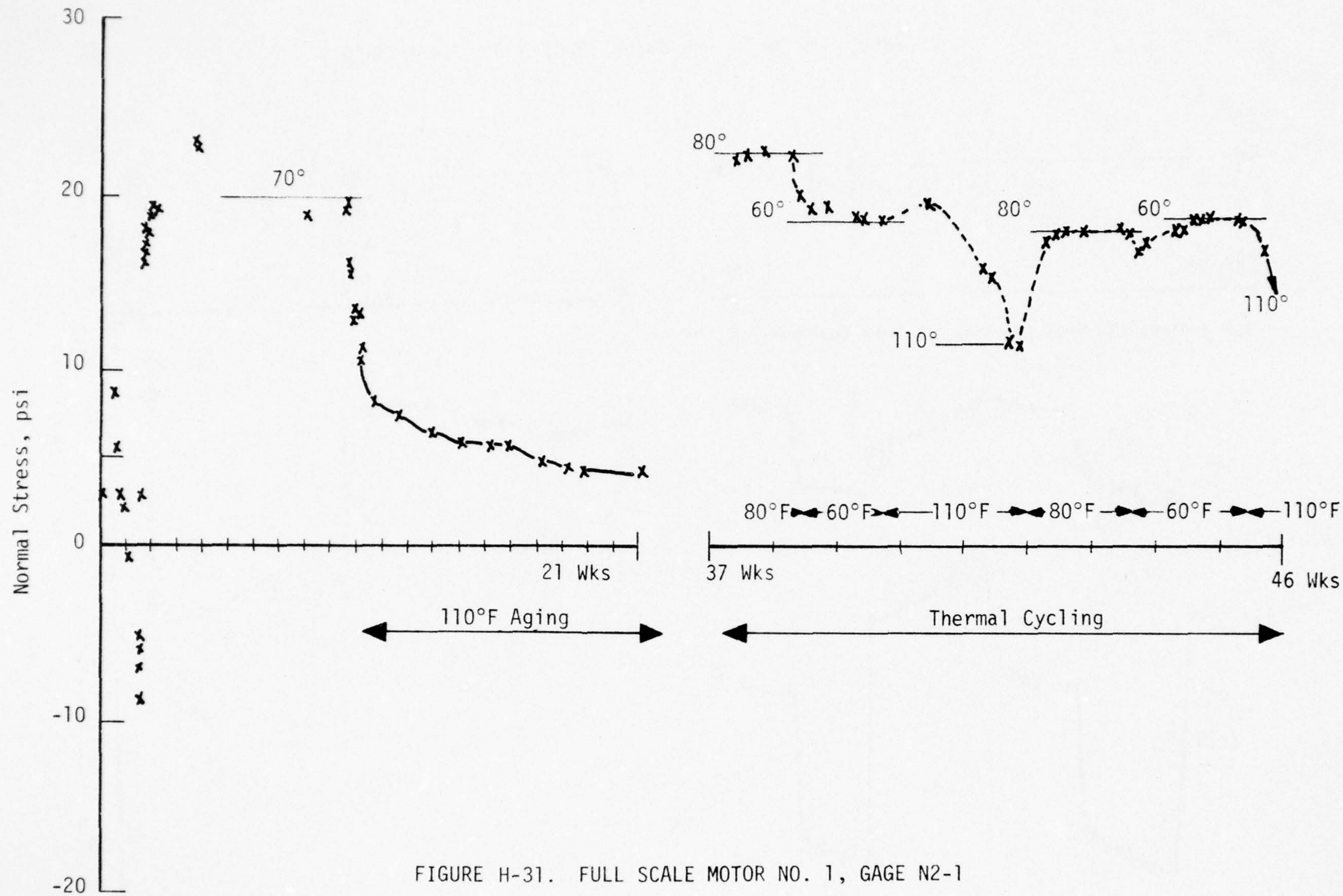


FIGURE H-31. FULL SCALE MOTOR NO. 1, GAGE N2-1

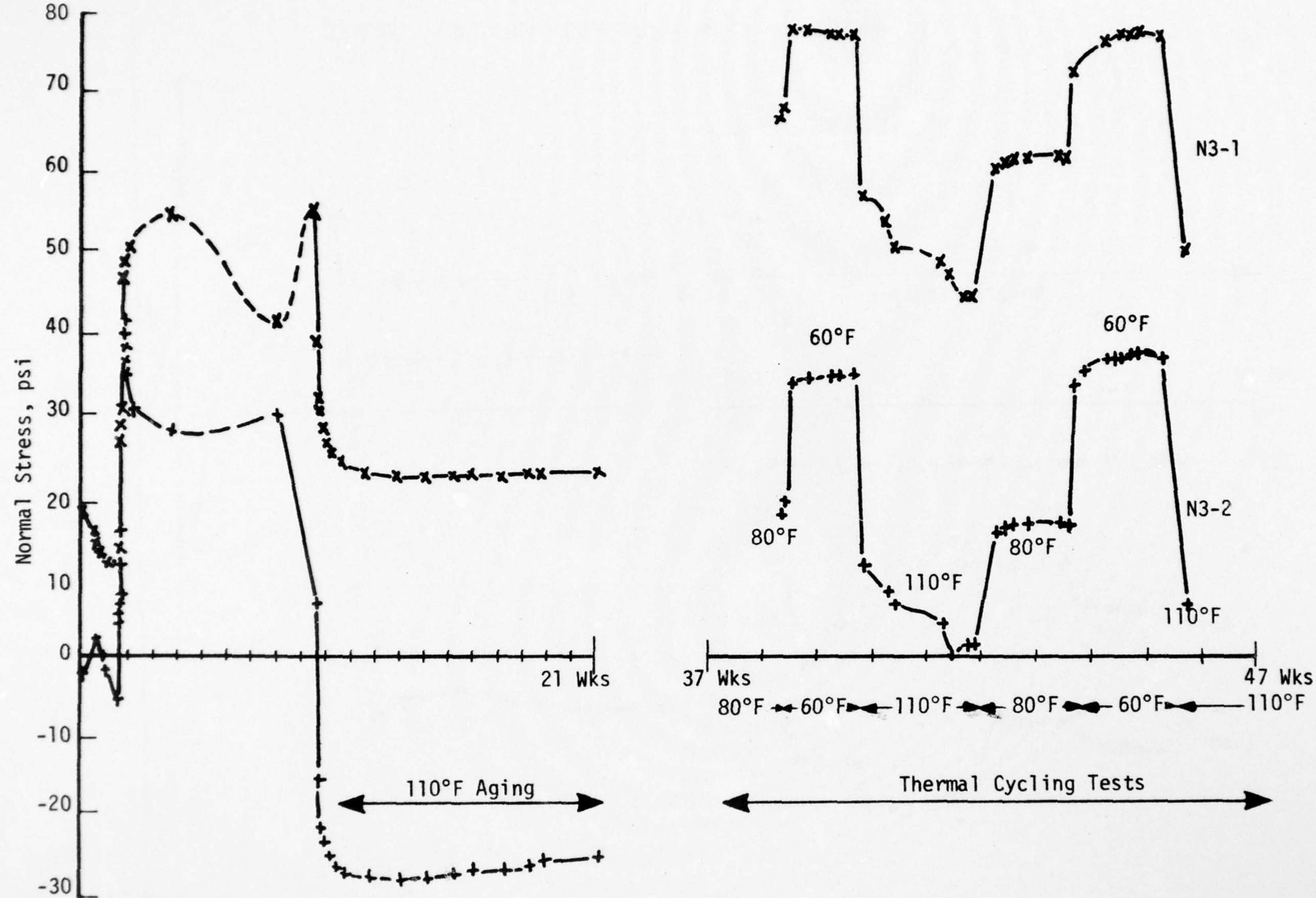


FIGURE H-32. FULL SCALE MOTOR NO. 1 - GAGES N3-1/2

AD-A032 637 AEROJET SOLID PROPULSION CO SACRAMENTO CALIF F/G 21/9.2
FLEXIBLE CASE-GRAIN INTERACTION IN BALLISTIC WEAPON SYSTEMS. VO--ETC(U)
OCT 76 K W BILLS, S W JANG, H LEEMING F04611-72-C-0055
UNCLASSIFIED ASPC-1953-81-F-VOL-3 AFRPL-TR-76-57-VOL-3 NL

3 OF 4
AD
A032637

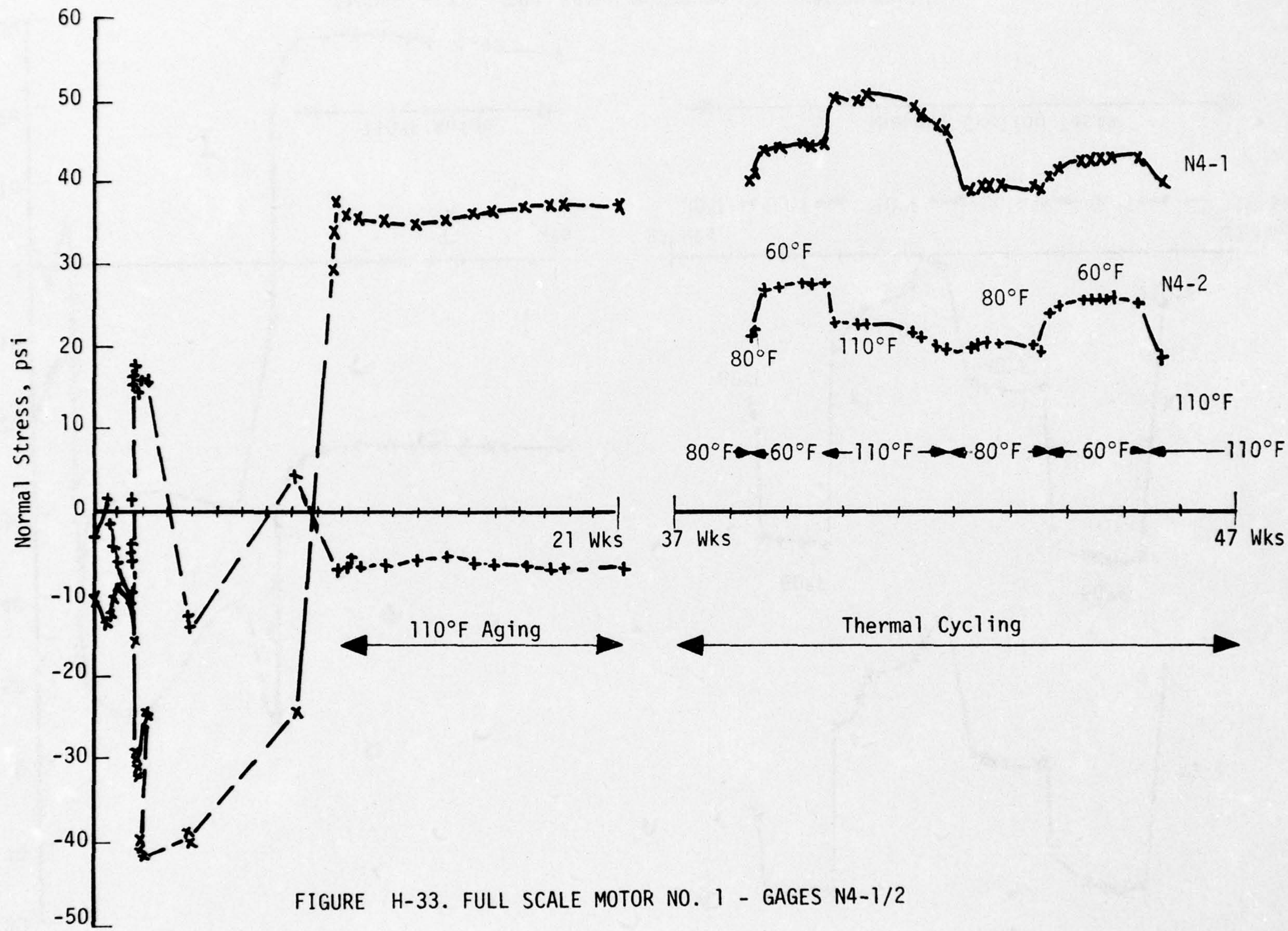


FIGURE H-33. FULL SCALE MOTOR NO. 1 - GAGES N4-1/2

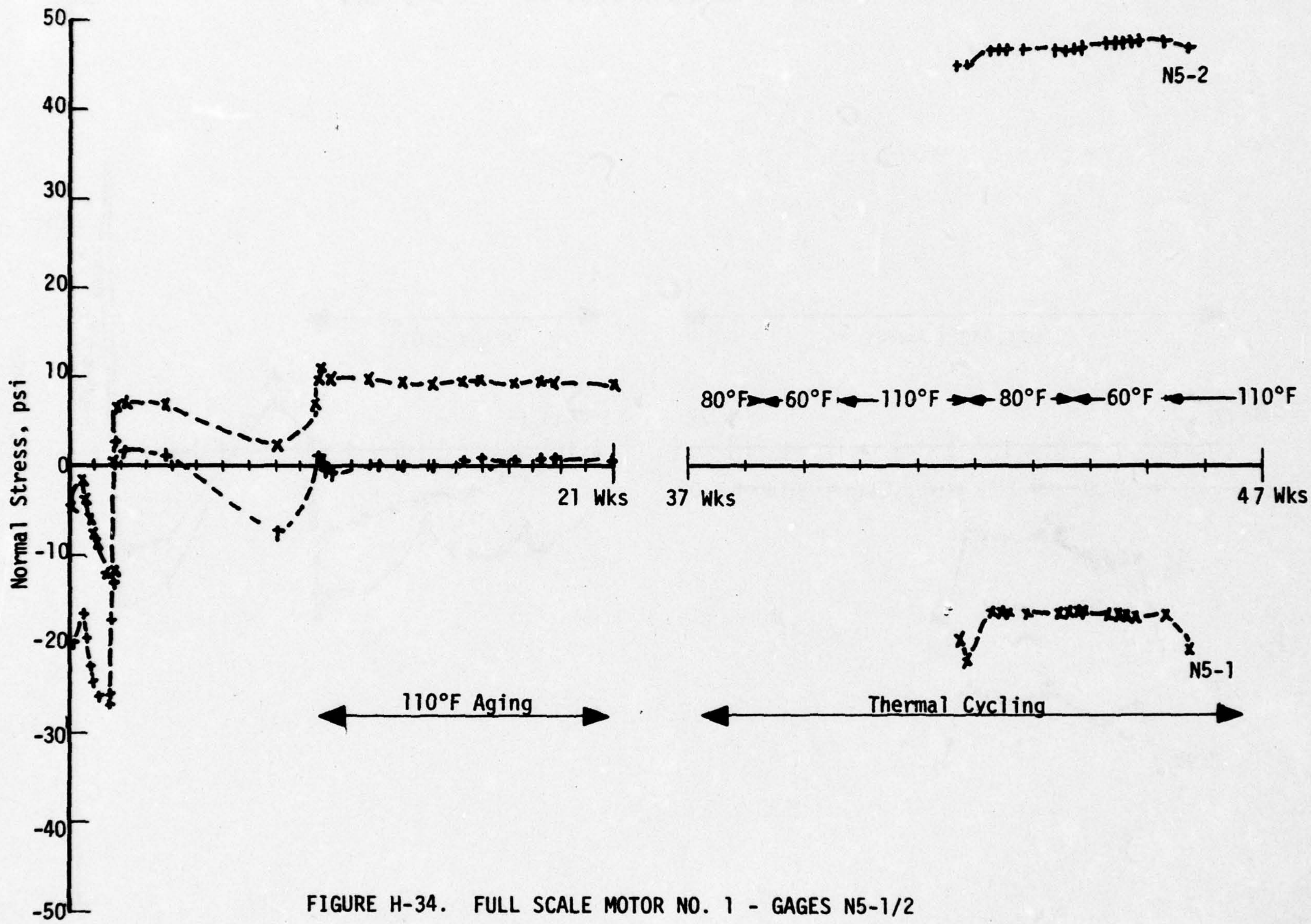


FIGURE H-34. FULL SCALE MOTOR NO. 1 - GAGES N5-1/2

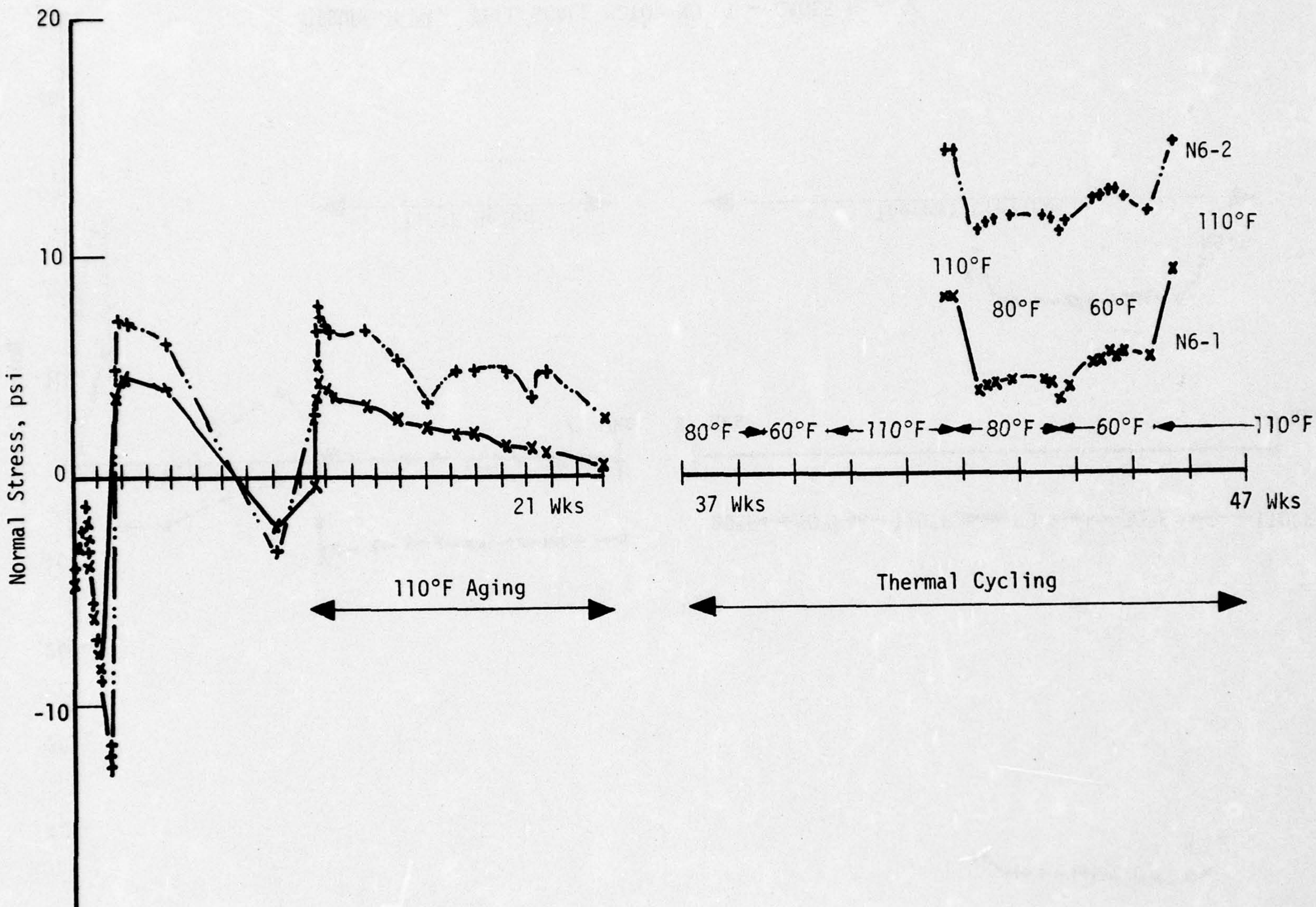


FIGURE H-35. FULL SCALE MOTOR NO. 1- GAGES N6-1/2

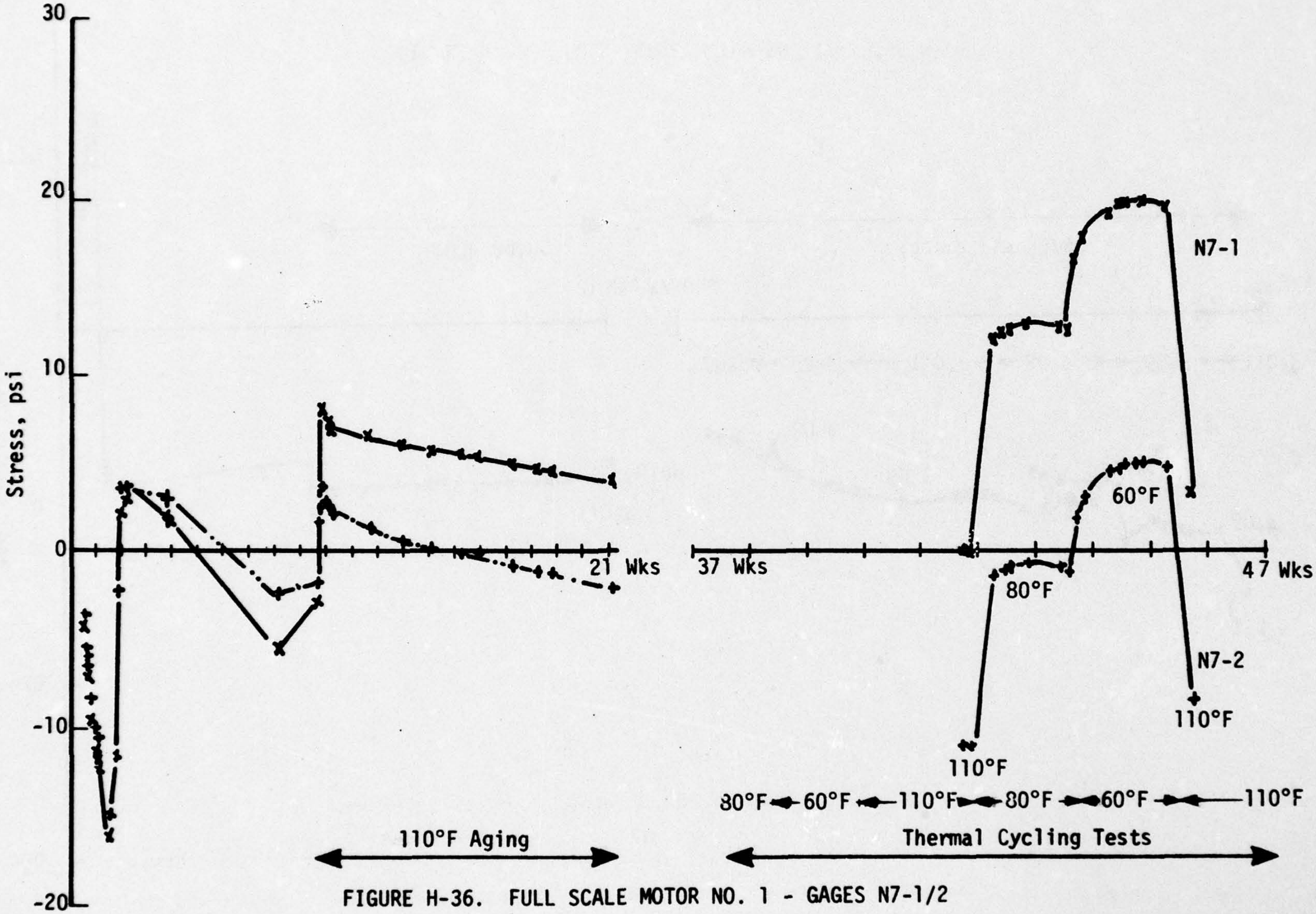


FIGURE H-36. FULL SCALE MOTOR NO. 1 - GAGES N7-1/2

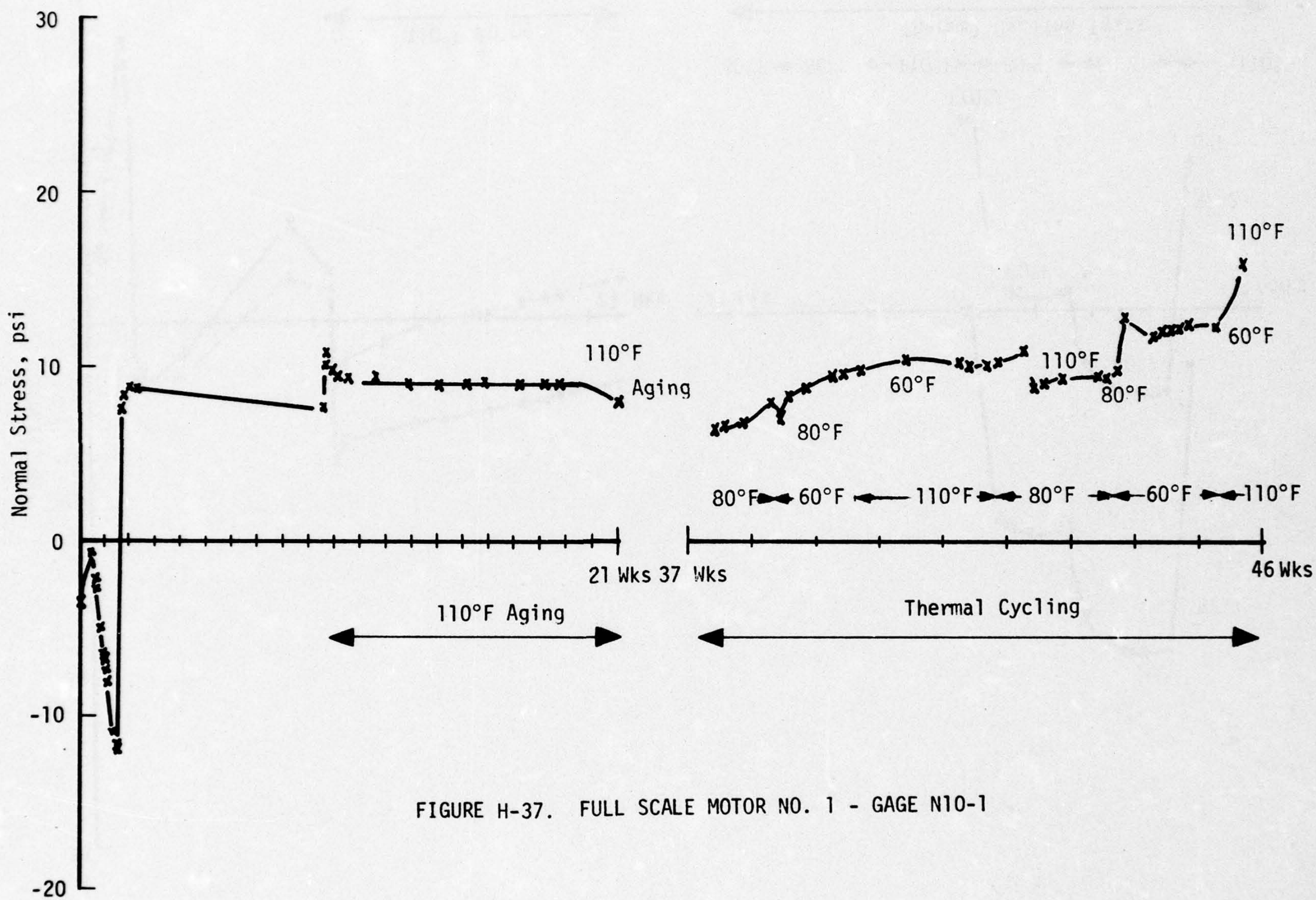


FIGURE H-37. FULL SCALE MOTOR NO. 1 - GAGE N10-1

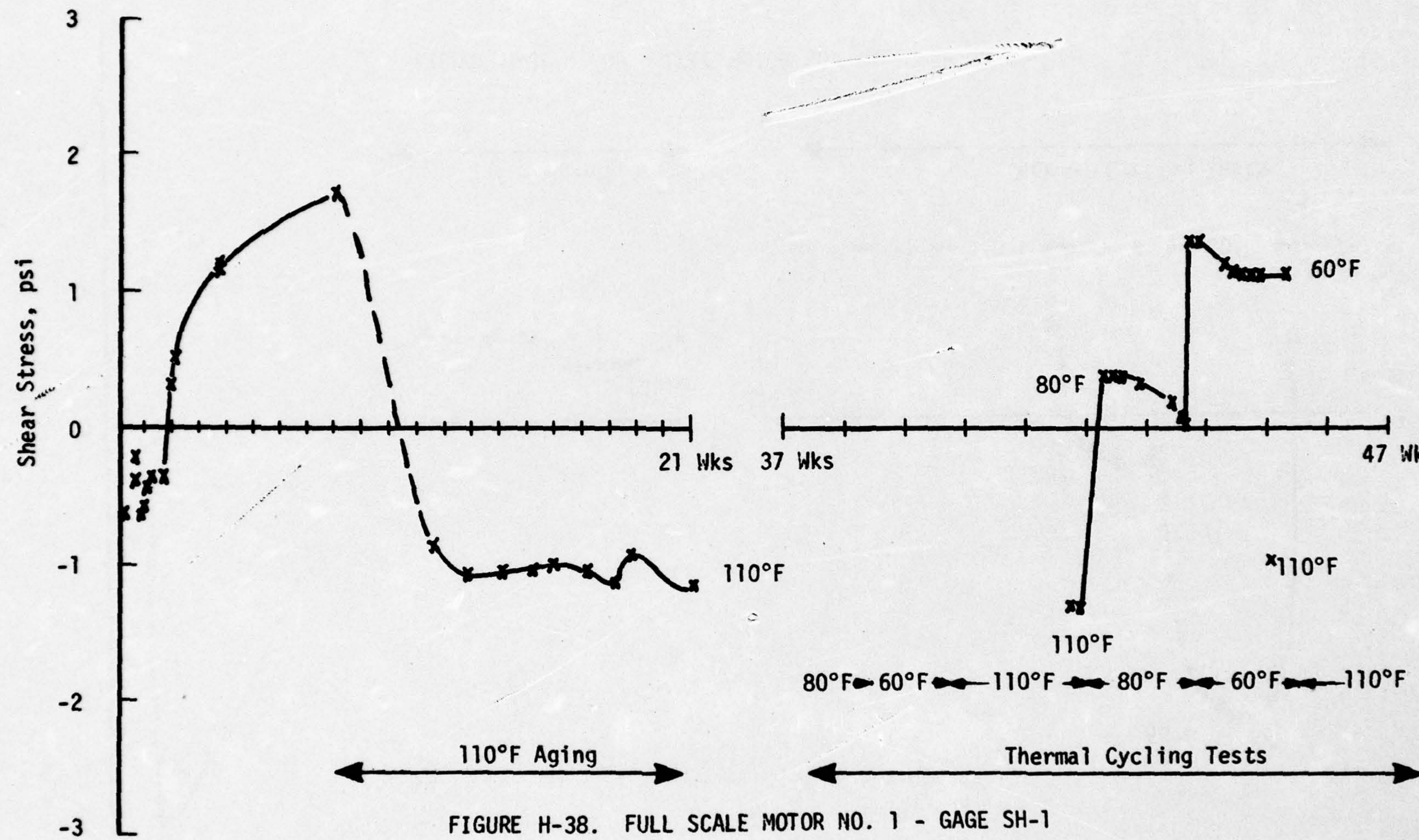


FIGURE H-38. FULL SCALE MOTOR NO. 1 - GAGE SH-1

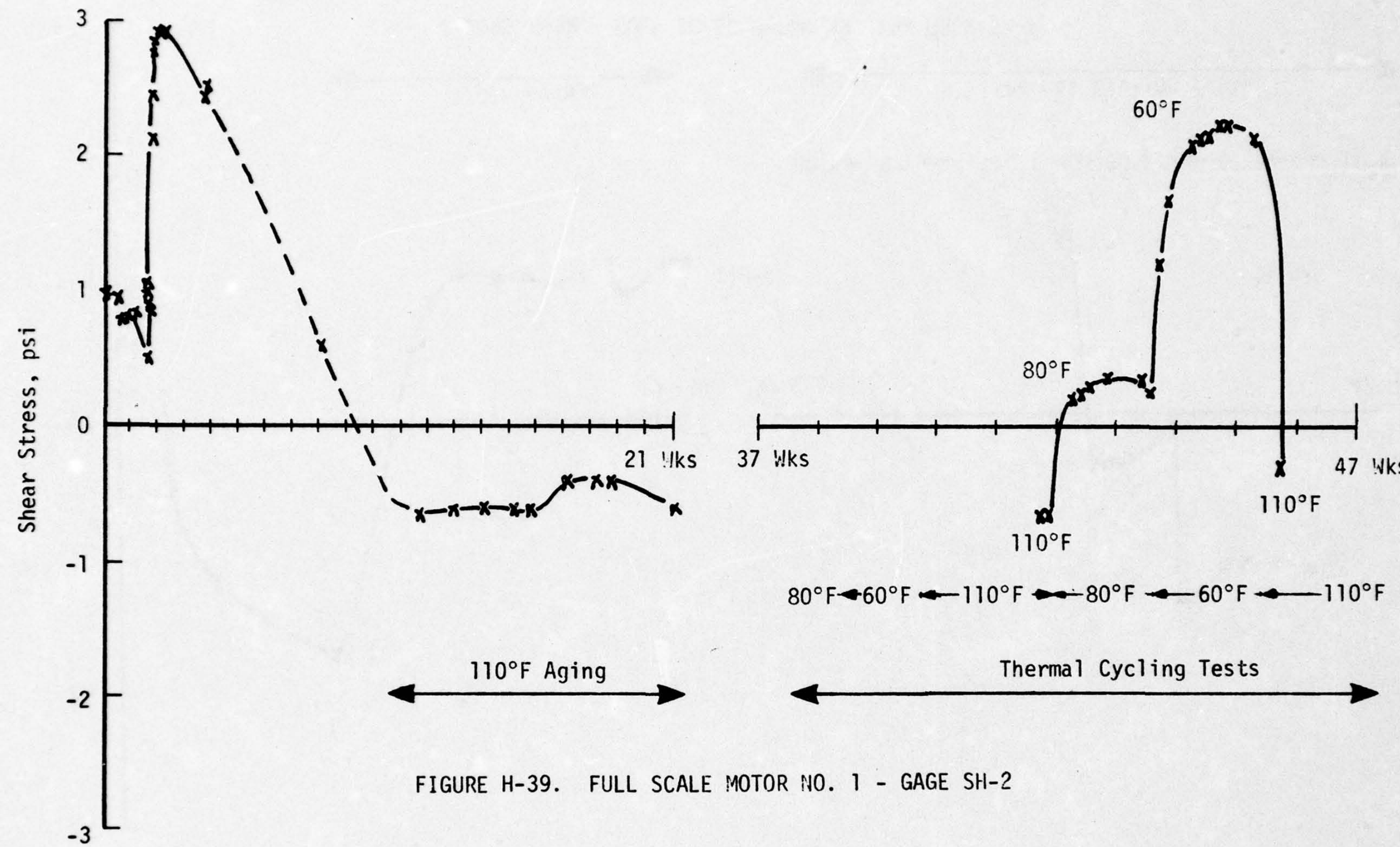


FIGURE H-39. FULL SCALE MOTOR NO. 1 - GAGE SH-2

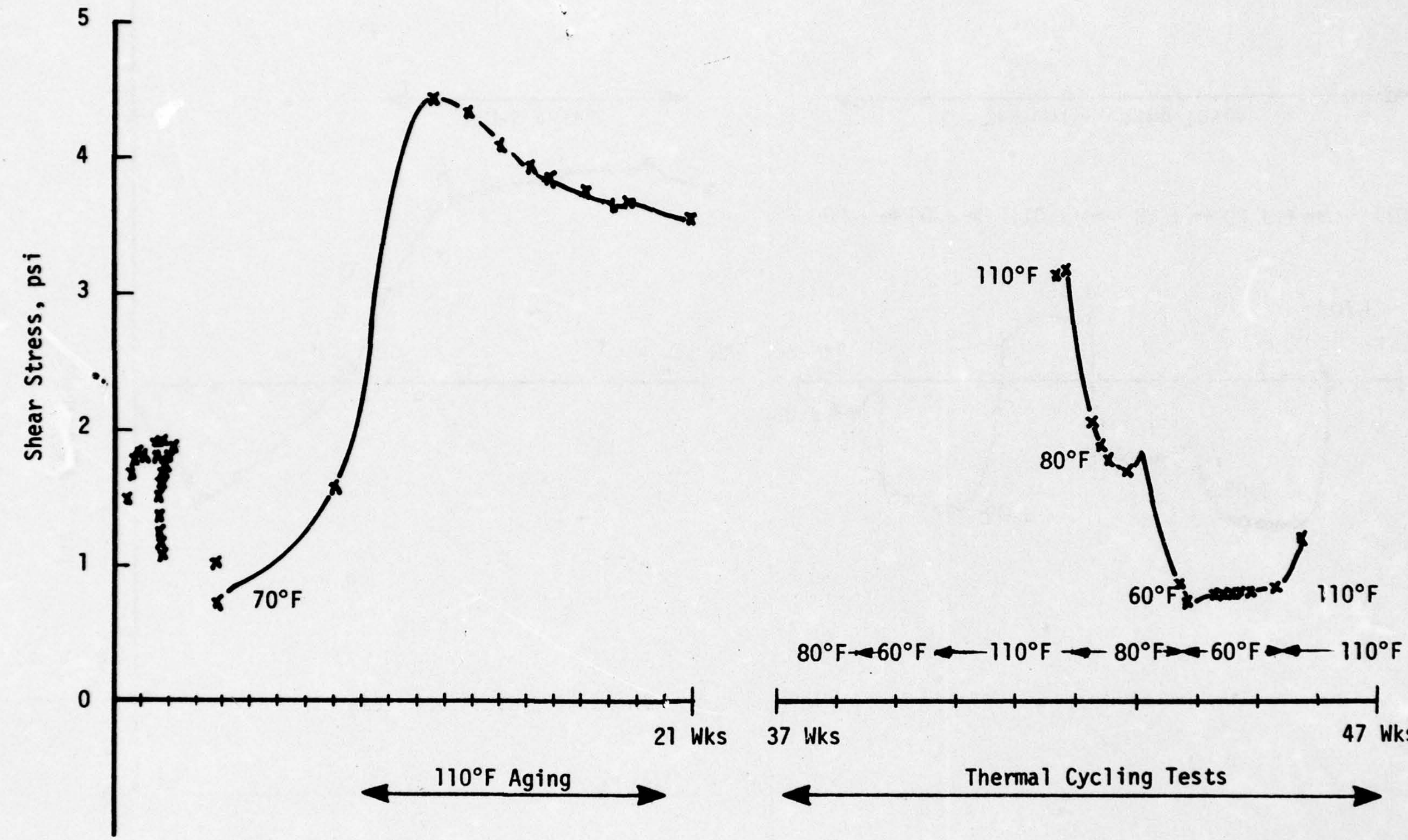


FIGURE H-40. FULL SCALE MOTOR NO. 1 - GAGE SH-4

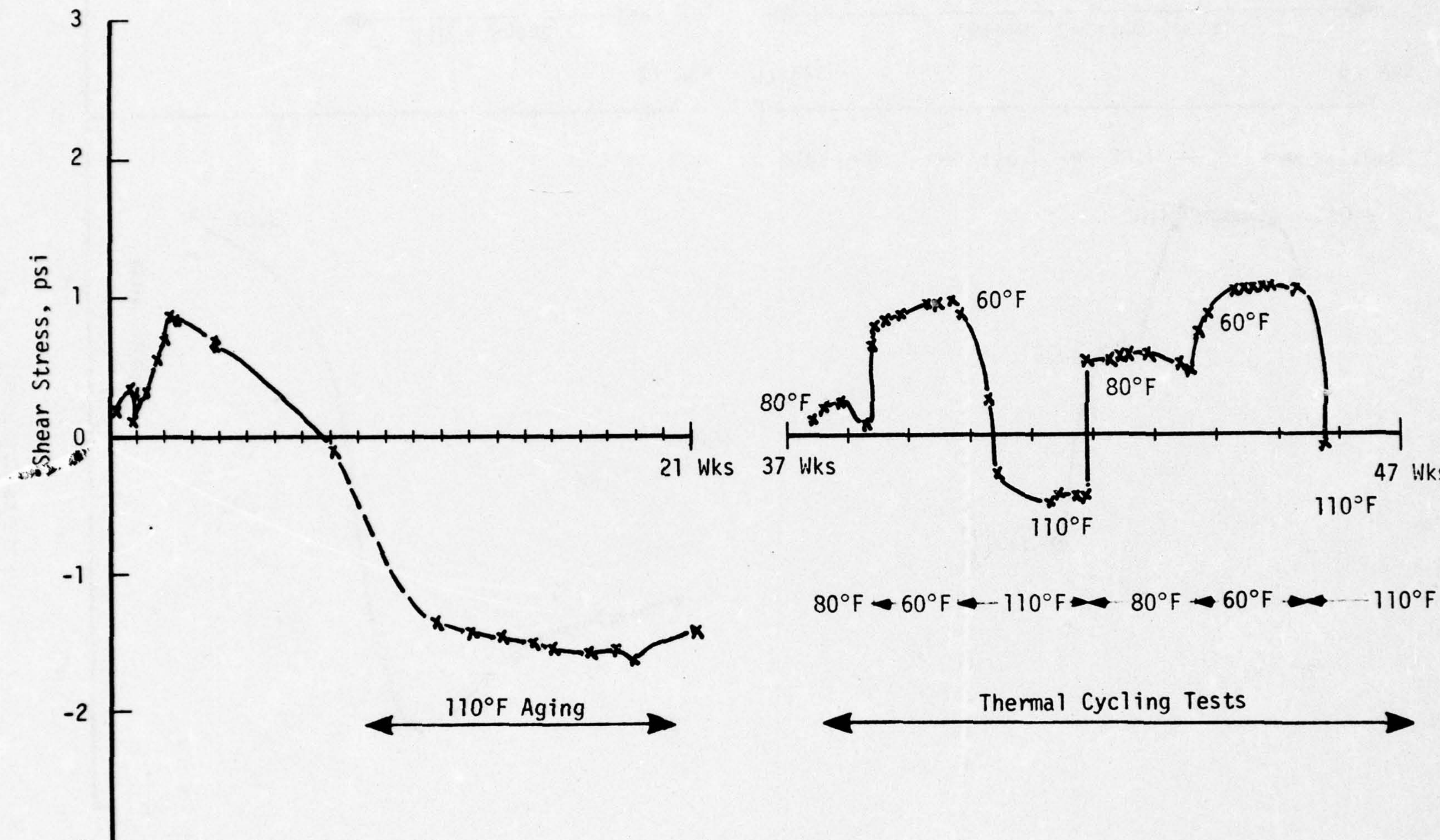


FIGURE H-41. FULL SCALE MOTOR NO. 1 - GAGE SH-5

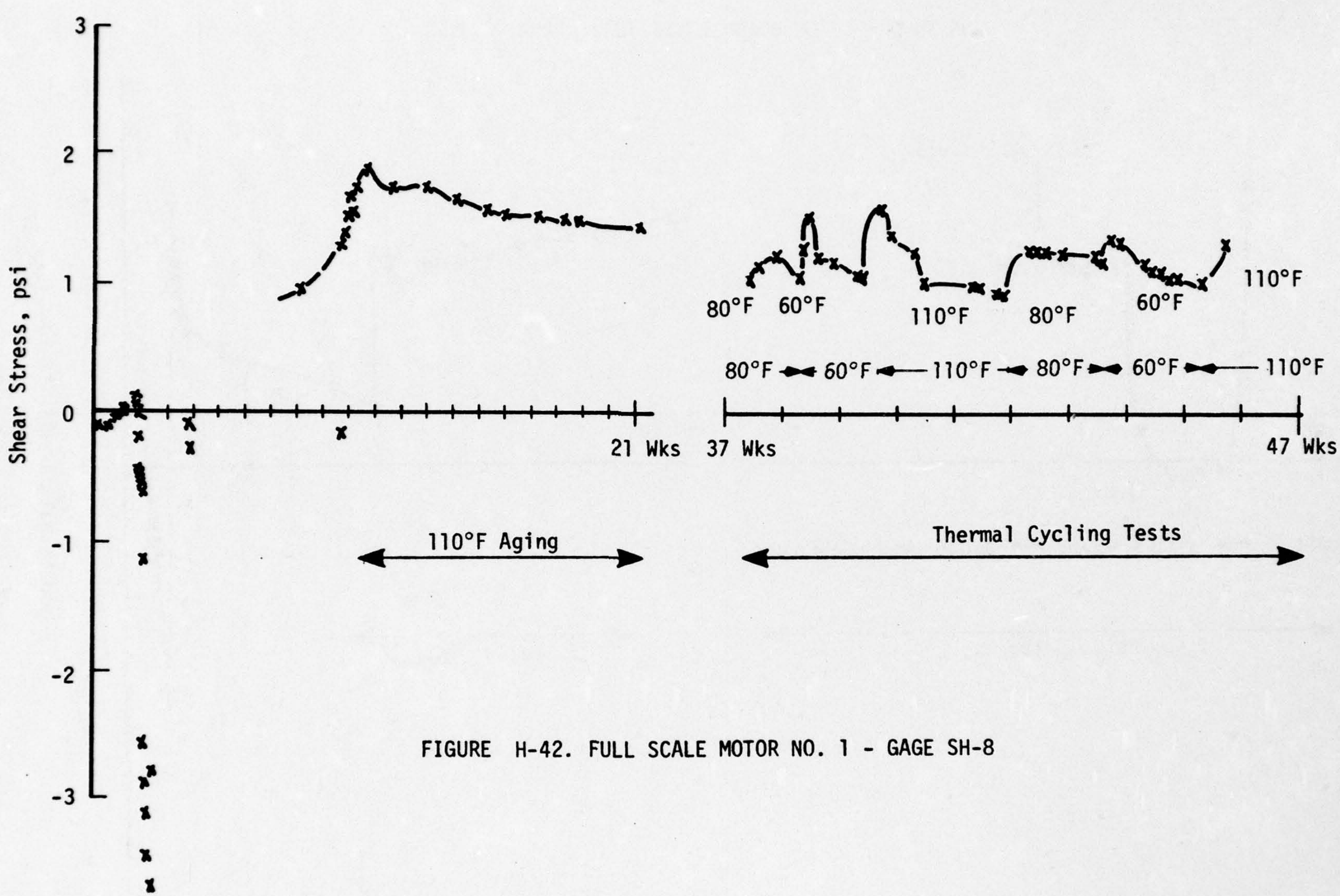


FIGURE H-42. FULL SCALE MOTOR NO. 1 - GAGE SH-8

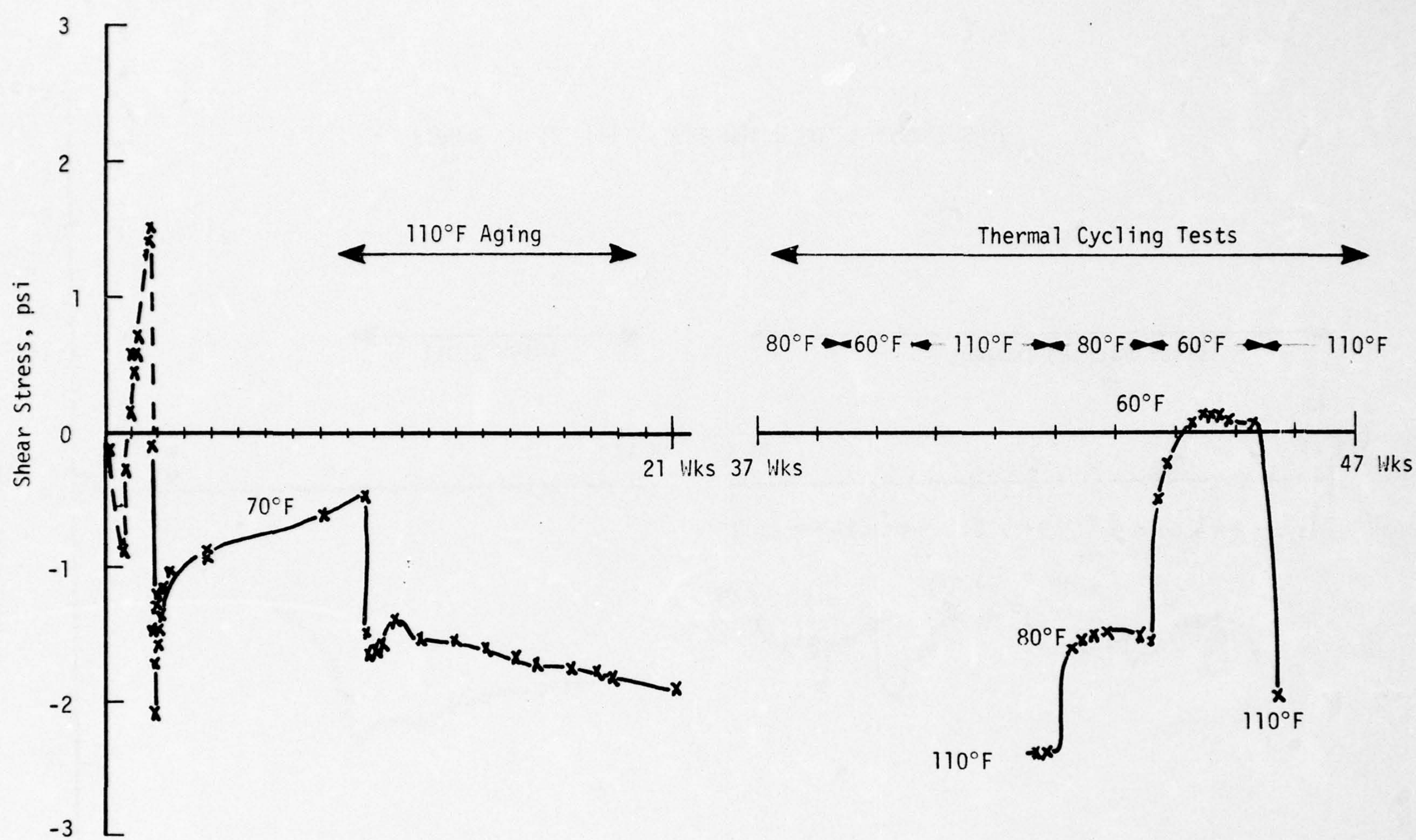


FIGURE H-43. FULL SCALE MOTOR NO. 1 - GAGE SH-9

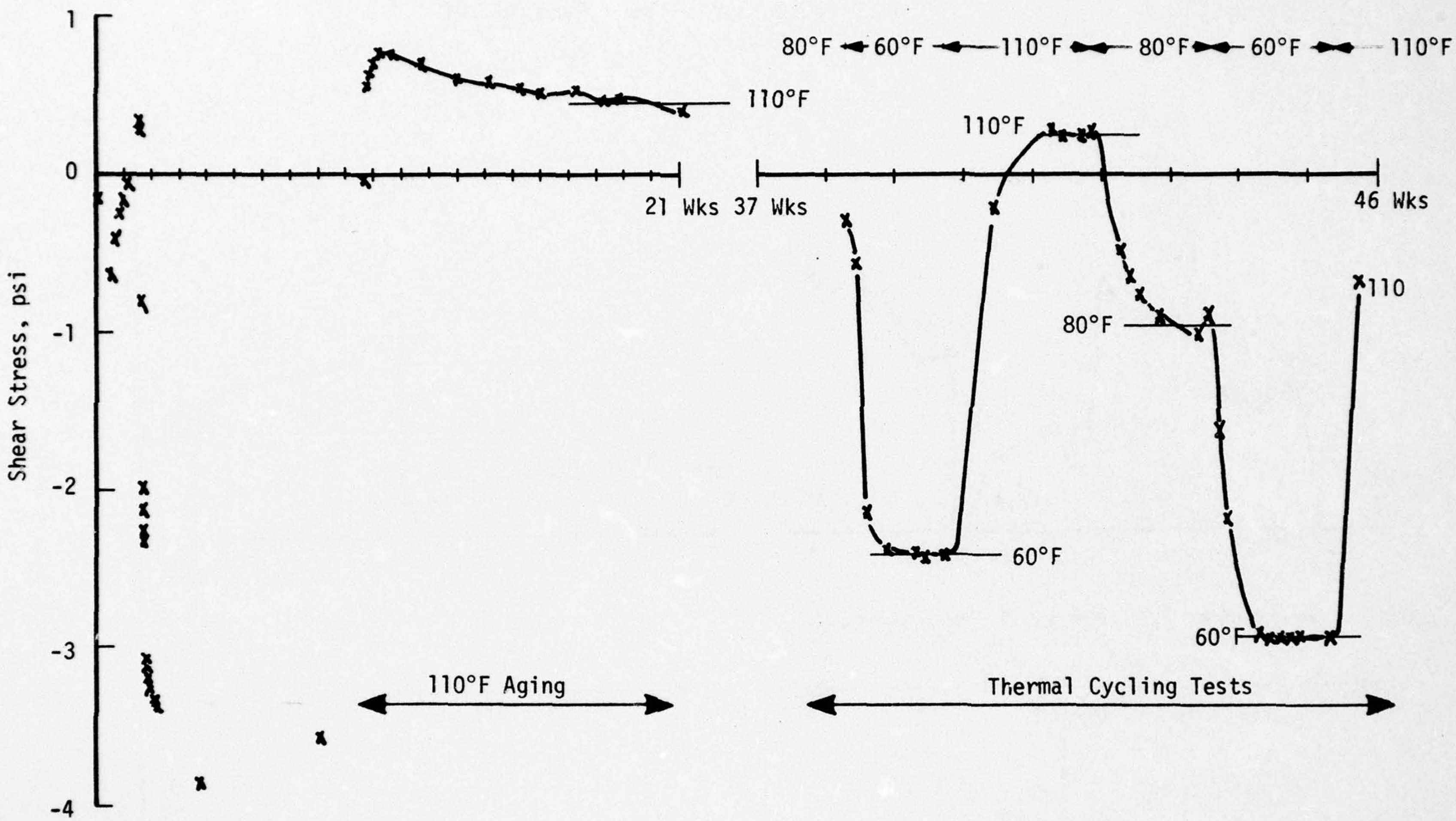


FIGURE H-44. FULL SCALE MOTOR NO. 1 - GAGE SH-10

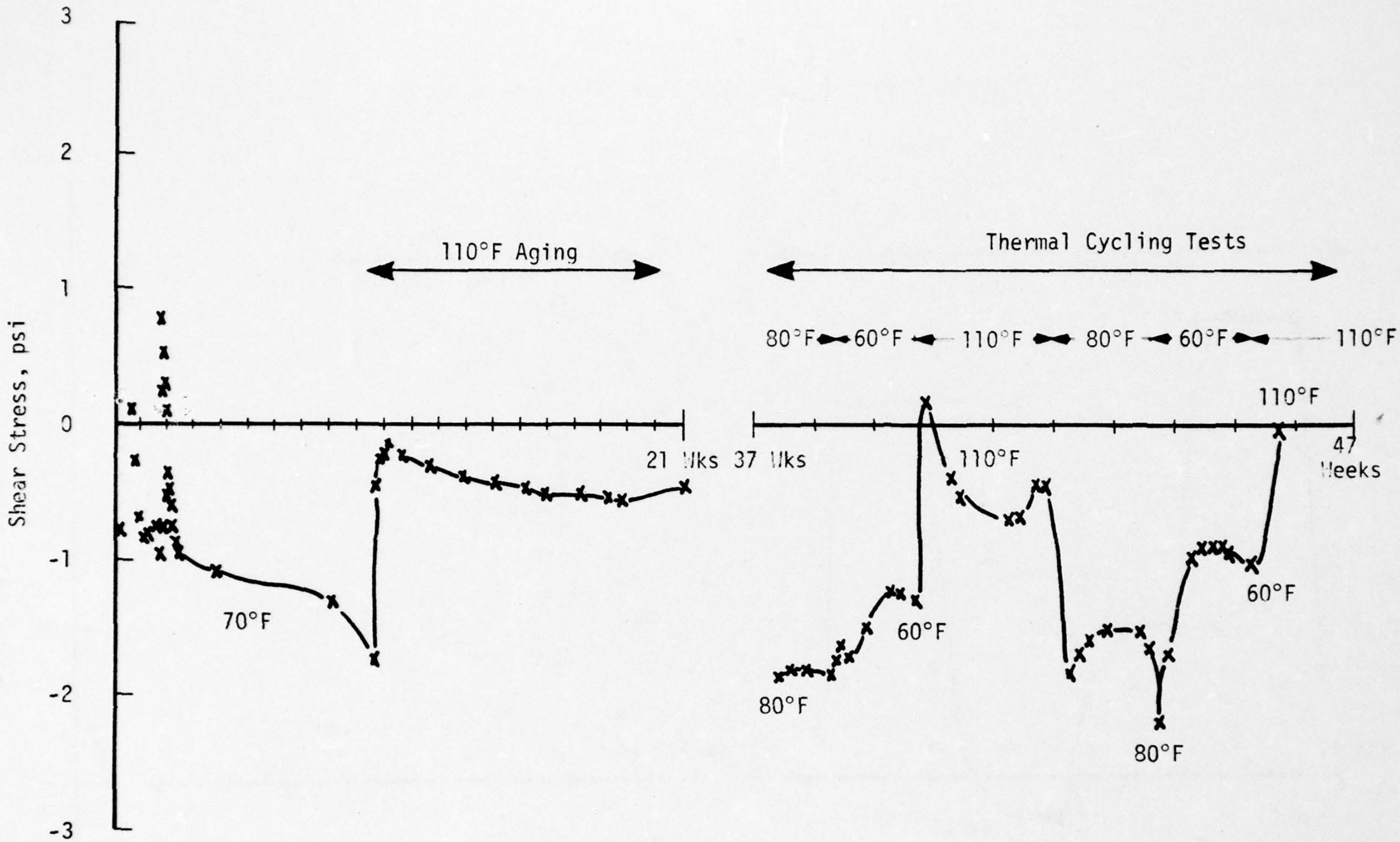


FIGURE H-45. FULL SCALE MOTOR NO. 1

GAGE SH-11

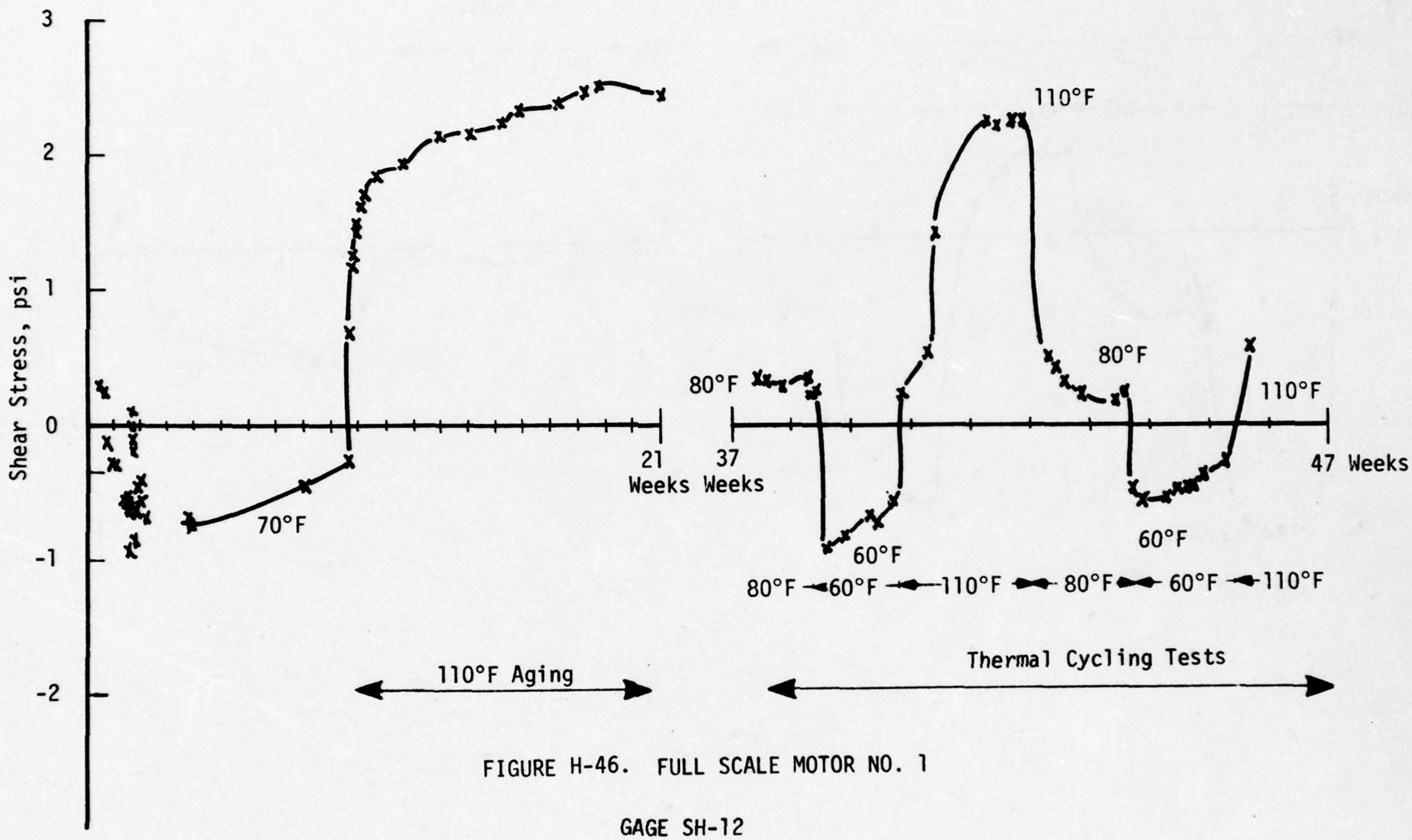


FIGURE H-46. FULL SCALE MOTOR NO. 1

GAGE SH-12

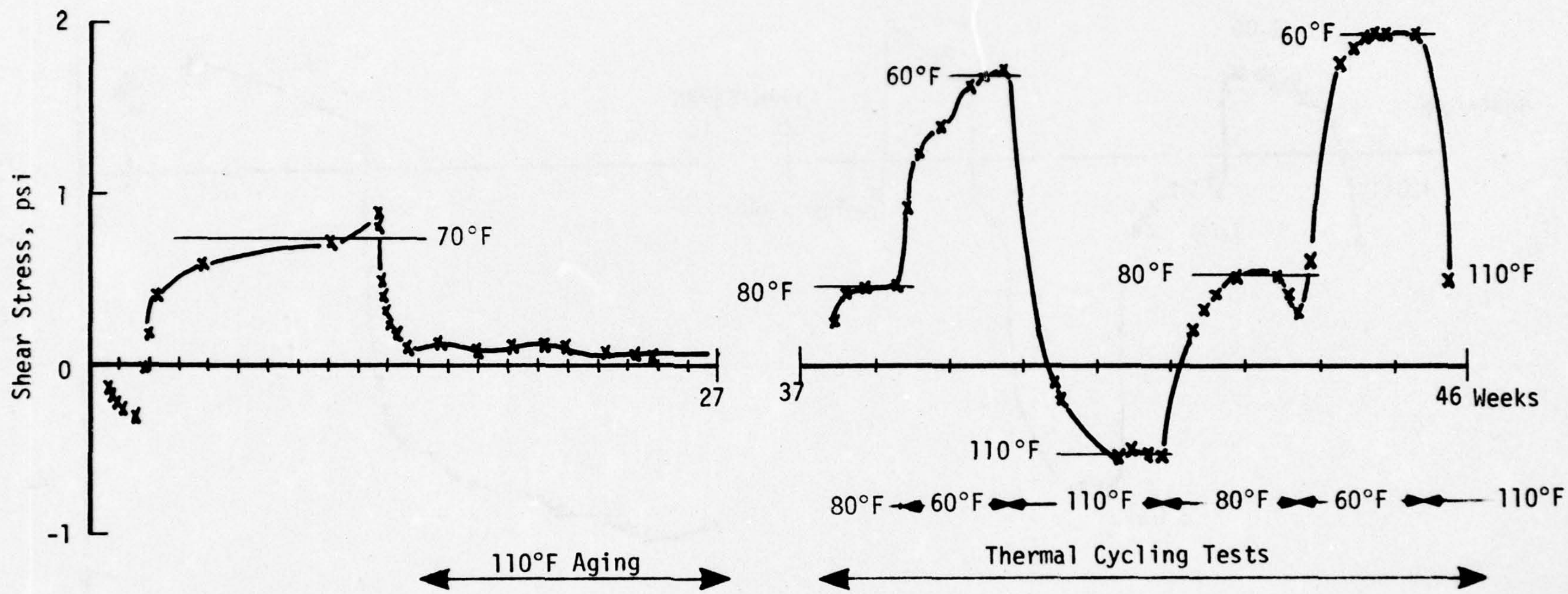


FIGURE H-47. FULL SCALE MOTOR NO. 1

GAGE SH14

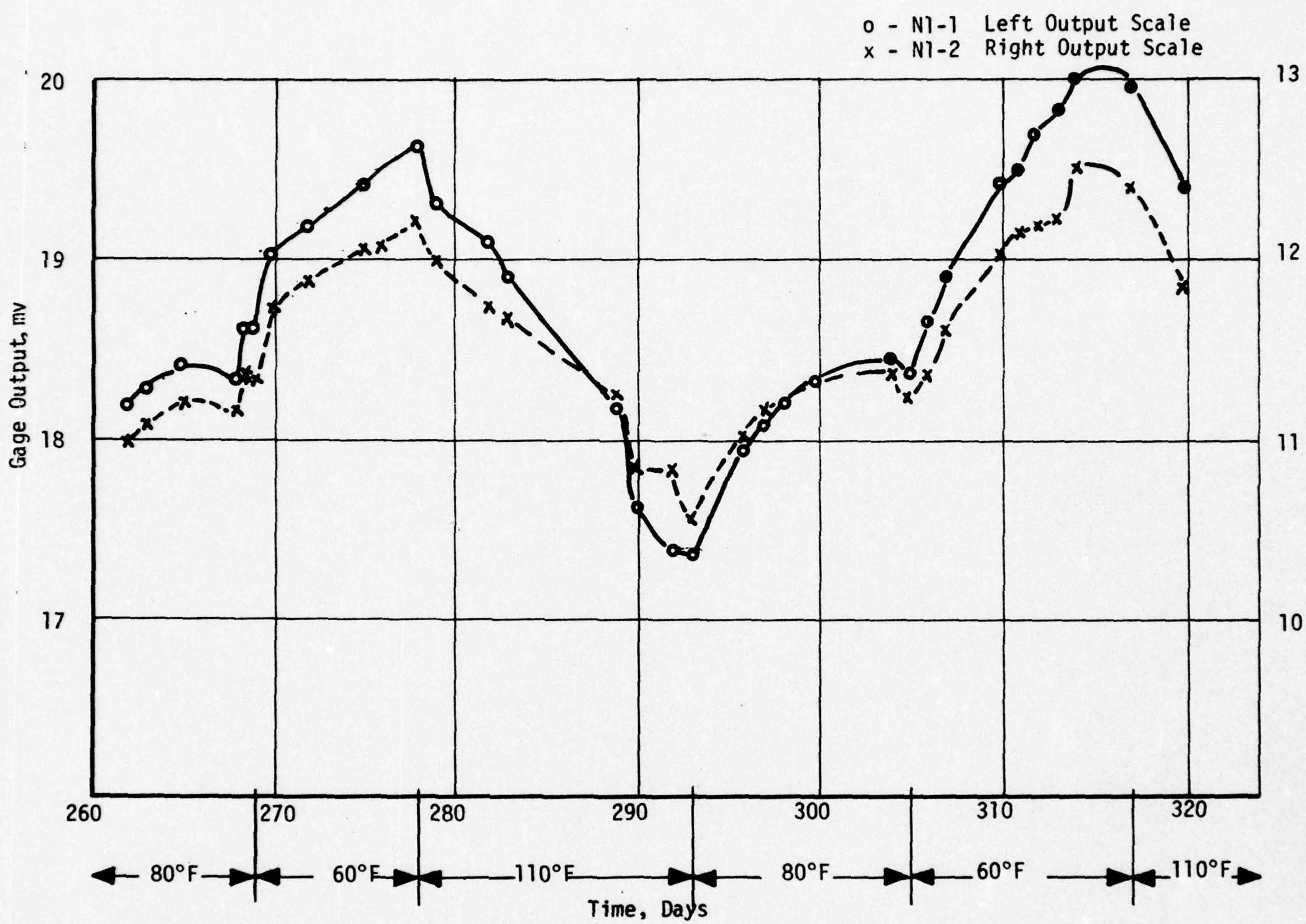


FIGURE H-48. FULL SCALE MOTOR NO. 1 - GAGES N1-1/2 OUTPUT (MV)

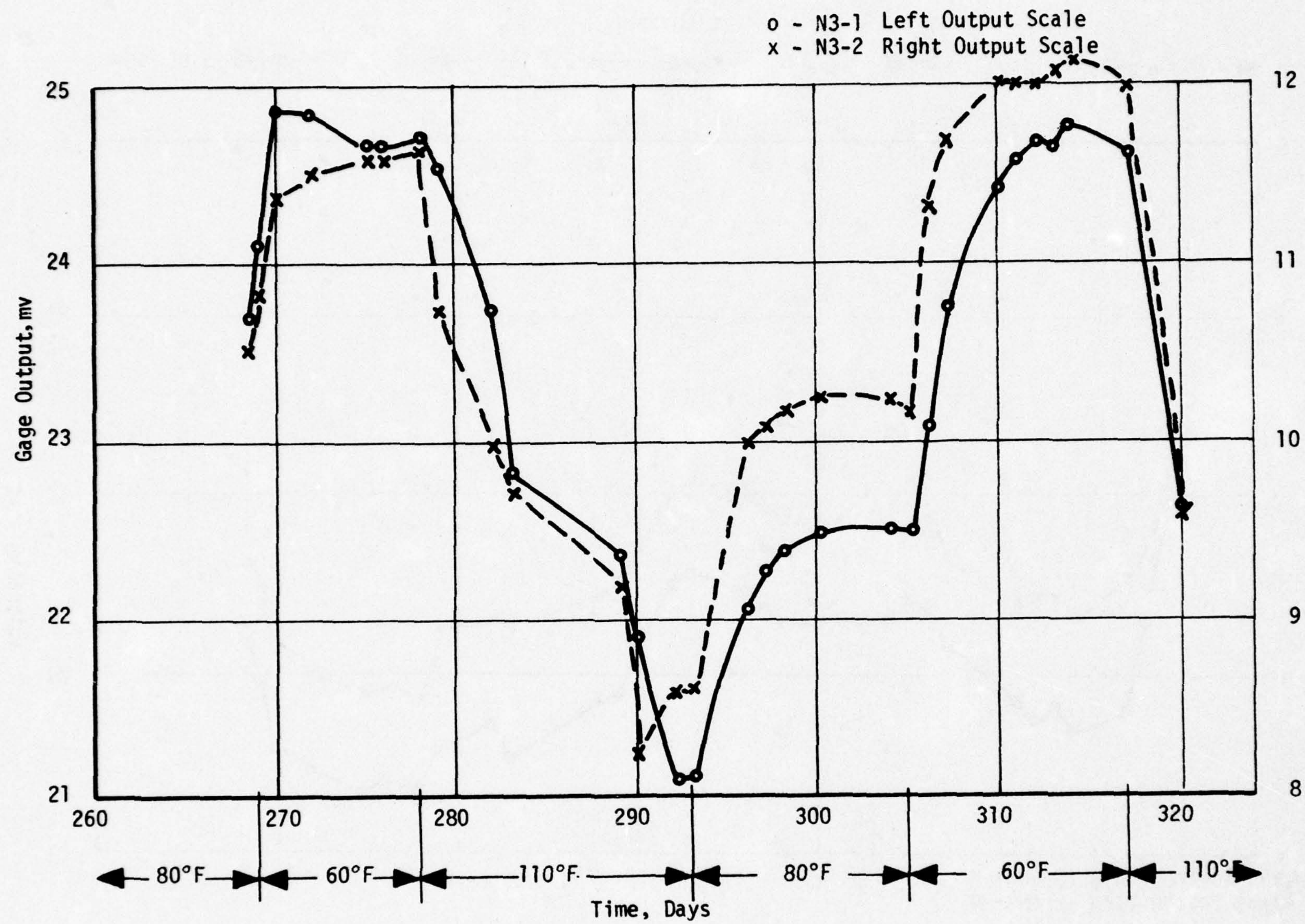


FIGURE H-50. FULL SCALE MOTOR NO. 1 - GAGES N3-1/2 OUTPUT (MV)

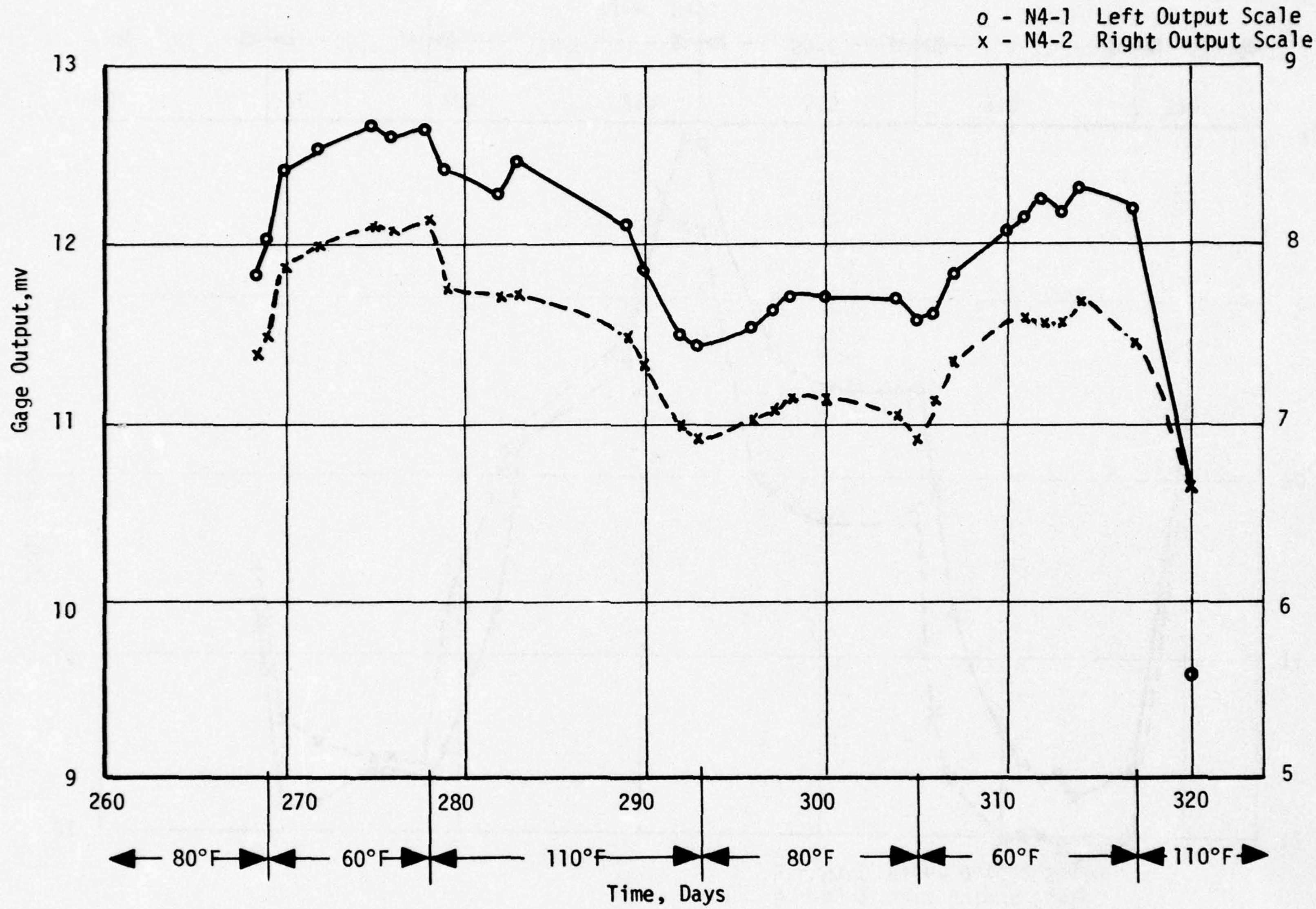


FIGURE H-51. FULL SCALE MOTOR NO. 1 - GAGES N4-1/2 OUTPUT

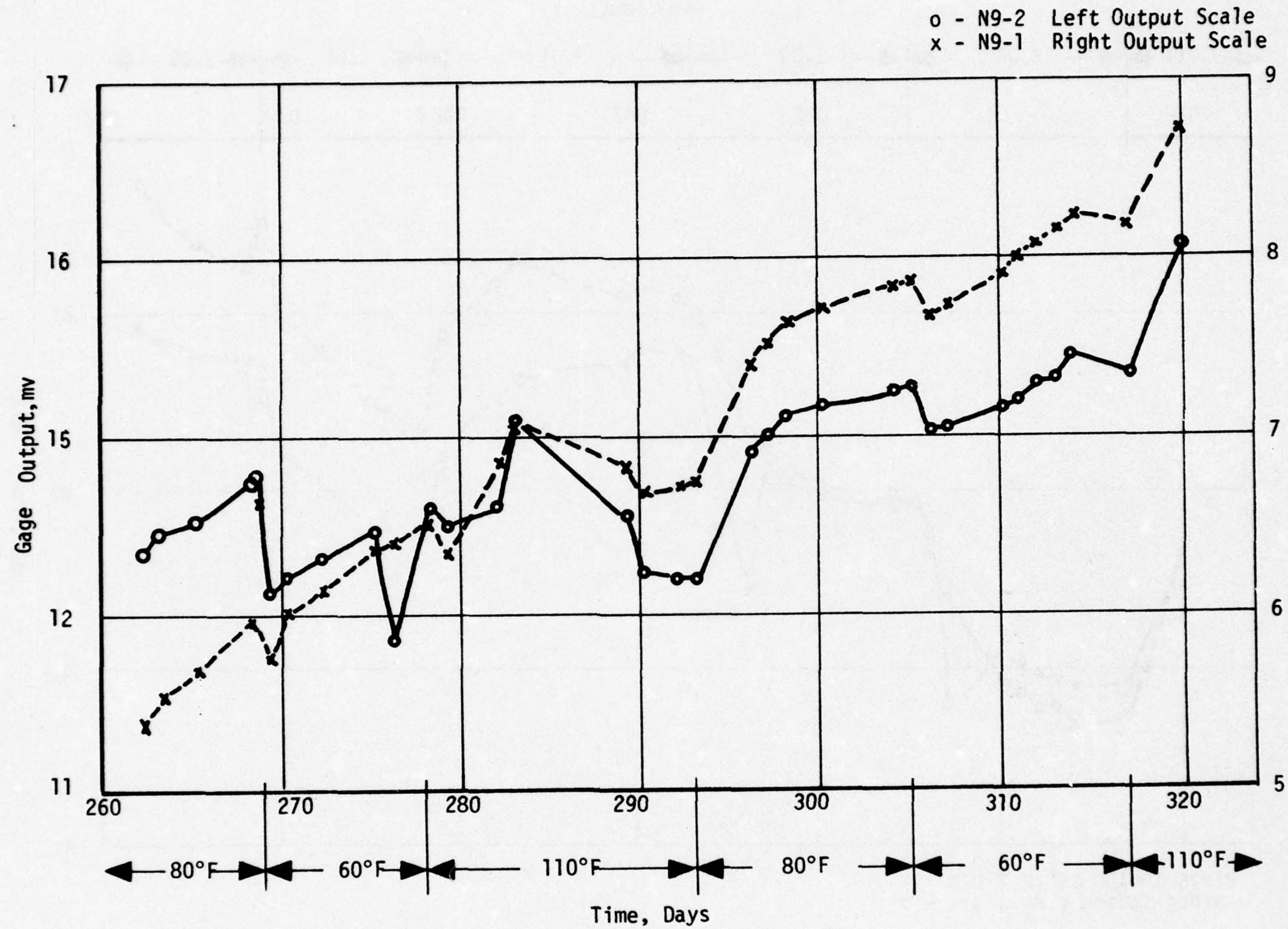


FIGURE H-52. FULL SCALE MOTOR NO. 1 - GAGES N9-1/2 OUTPUT (MV)

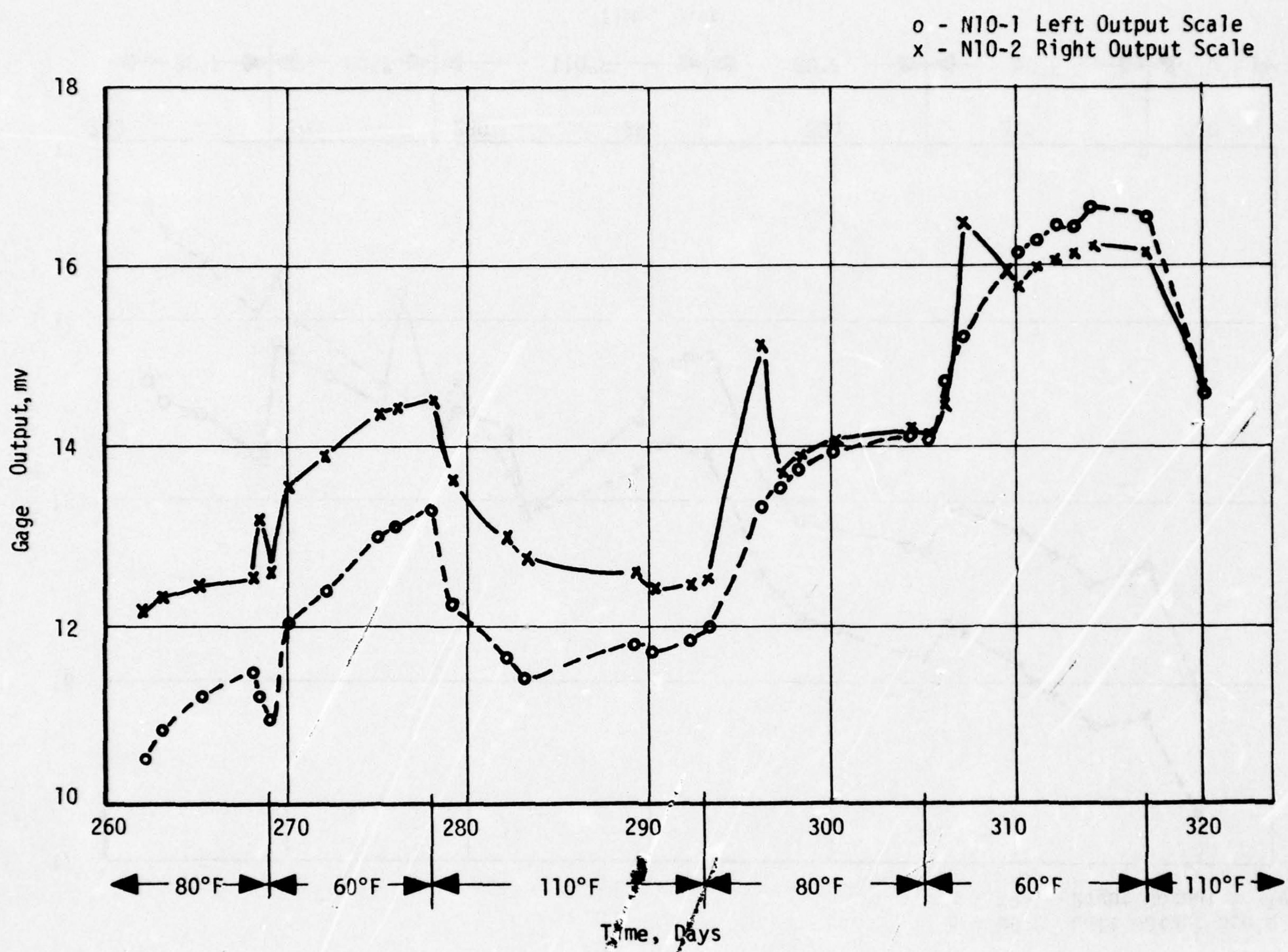


FIGURE H-53. FULL SCALE MOTOR NO. 1 - GAGES N10-1/2 OUTPUT (MV)

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	N12 -1	N12 -2
Konigsberg gage calibration	Zero load gage output	Sept.			30	0	.32	-.24	.69	.77	-.34	-.89	1.24	-.18	.67	.14	1.28	.97	.13	-.47	-.12	-.54	.78	.80	.28	-.32	-.68	-.08		
		Oct.			80		.39	.21	-3.16	1.19	.24	.36	.53	-.29	.31	.37	.08	.22	.64	.30	.19	.23	.34	.35	.44	.33	.35	.26		
		1972			130		-.22	-.30	1.32	1.28	-.67	.90	1.08	-.34	-.07	.12	.40	.32	.45	.23	.07	.07	.52	.34	-.01	.79	.25	-1.68		
	Gage sensitivity	"			30	0-150	.274	.268	.273	.268	.270	.267	.270	.274	.813	.811	.808	.805	.799	.803	.819	.821	.807	.814	.821	.825	.826	.823		
	mv/psi				80	(N2:	.275	.270	.275	.269	.272	.270	.273	.272	.818	.813	.812	.806	.801	.805	.814	.825	.812	.812	.819	.813	.823	.822		
					130	0-450)	.277	.273	.276	.270	.274	.270	.271	.270	.822	.818	.813	.810	.800	.808	.822	.826	.815	.813	.815	.823	.825	.816		
ASPC calibrations.	Gages with same bridge	10-12-72			77	0	3.000	-.25	.912	-3.00	-2.83		1.52	30.54	-2.10	-.83	2.23	1.59	18.71	-.16	-3.01	-4.89	.50	-.15	-4.75	-1.10	1.64	-2.35		
Vacuum tests.	boards later installed					-2.2	2.272	-.925	-.45	-3.71	-3.64		.94	29.97	-3.90	-1.14	.52	.15	17.00	-1.95	-4.90	-6.69	-1.23	-1.97	-6.60	-2.94	-.18	-4.24		
	on motor.					-4.7	1.577	-1.688	-.23	-4.20	-4.05		.17	29.26	-5.90	-1.49	-1.62	-2.23	14.87	-4.02	-7.12	-8.77	-3.35	-4.03	-8.75	-5.10	-2.39	-6.47		
(The signs of the recorded values for N2-1 and N4-2 have been reversed to show a positive response to an increasing compressive stress)						-6.7	1.039	-2.248	-.97	-4.79	-4.62		-.34	28.74	-7.56	-1.77	-3.15	-3.81	13.35	-5.59	-8.74	-10.37	-4.85	-5.60	-10.30	-6.80	-3.97	-8.05		
						-8.7	.517	-2.823	-1.56	-5.30	-5.02		-.88	28.26	-9.11	-2.05	-4.66	-5.34	11.78	-7.23	-10.74	-11.92	-6.50	-7.25	-11.94	-8.37	-5.65	-9.65		
						-10.7									-10.66	-2.32	-6.26	-6.93	10.19	-8.77			-8.08	-8.75	-13.50	-10.06	-7.33	-11.24		
						-9.7																	-7.26	-7.99	-12.74					
						-7.7	.825								-8.27	-1.92	-3.90	-4.61	12.52	-6.44			-5.73	-6.42	-11.14					
						-5.7	1.355	-2.044					.01	29.07	-6.73	-1.64	-2.28	-3.00	14.21	-4.83	-7.84	-9.65	-4.08	-4.75	-9.55	-5.96	-3.32	-7.16		
						-3.7	1.890	-1.532					.60	29.64							-6.24	-8.02	-2.67	-3.25	-7.90	-4.37	-1.70	-5.59		
						-1.7																	-.80	-1.49	-6.21					
						0	2.980	-.477	1.11	-2.85	-2.87		1.73	30.78	-1.97	-.85	2.45	1.69	18.82	-.10	-2.87	-4.72	.49	-.14	-4.75	-1.13	1.52	-2.40		
	*N4-2 rebalanced to					0						4.80		-1.858* -2.00		-3.71		1.68	-.06											
	give -1.858, -2.0 mv					-2.7						4.28				-5.29		-.54	-2.47											
	at 0 psig					-4.7						3.50				-6.80		-2.20	-4.15											
						-6.7										-8.20		-3.78	-5.76											
						-8.7										-9.65		-5.32	-7.29											
						[illegible]										-8.97		-4.55	-6.58											
						[illegible]										-7.53		-2.98	-4.98											
						[illegible]										-3.04		1.80	-.19											
0-15 psi pressurization	Gages installed in				~75	[illegible]									-4.80	-5.86	-7.50	-3.78	-3.45	.79										
	chamber. Chamber					[illegible]									-4.73	-5.84	-7.47	-3.24	-3.70	.36										
	horizontal. Prior					[illegible]									-.72	-2.15	-3.54	.64	.35	4.36										
(The signs of the recorded values for N1-2, N2-2, N5-1, N6-2, N7-2, N9-1, and N11-2 have been reversed to show a positive response to an increasing compressive stress)	to casting.					[illegible]									-.74	-2.17	-3.56	.62	.35	4.34										
						[illegible]									3.46	1.71	.58	4.72	4.55	8.51										
						[illegible]									3.49	1.74	.61	4.76	4.59	8.54										
						[illegible]									7.08	5.42	4.55	8.70	9.13	13.23										
						[illegible]									7.52	5.48	4.60	8.75	9.13	13.18										
						[illegible]	-5.56	-7.51	1.25	-11.67	-5.37	4.63	-.76	-1.48							2.52	2.50								
						[illegible]	-	-7.30	2.16	-	-5.20	-	-.79	-1.47							2.49	2.49								
						[illegible]	-5.51	-7.33	1.87	-11.90	-5.13	4.80	-.79	-1.48							2.49	2.49								
						[illegible]	-3.50	-5.34	3.18	-10.08	-3.73	6.26	.58	-.11							6.55	6.66								
						[illegible]	-3.61	-5.47	3.16	-10.08	-3.71	6.26	.58	-.11							6.56	6.69								
						[illegible]	-2.59	-4.49	4.55	-9.09	2.45	7.58	1.99	1.29							10.80	11.04								
						[illegible]	-2.68	-4.57	4.37	-9.23	2.42	7.64	1.95	1.25							10.67	10.93								
						[illegible]	-1.43	-3.31	5.87	-9.35	1.60	9.20	3.35	2.64							14.93	15.24								
						15	-1.39	-3.26	5.93	-9.42	1.55	9.24	3.38	2.68							14.95	15.33								
						15																	12.48	1.58	8.85	4.66	15.43	-2.43		
						15																	12.46	1.57	8.89	4.69	15.75	-2.37		
						10																	8.46	-2.40	4.81	.64	11.34	-6.38		
						10																	8.40	-2.47	4.77	.58	11.27	-6.50		
						5																	4.63	-6.26	.82	-3.32	7.60	-10.07		
						5																	4.77	-6.15	.93	-3.21	7.69	-9.98		
						0																	2.96	-10.54	-3.42	-7.56	3.14	-14.38		
						0																	2.96	-10.55	-3.42	-7.56	3.13	-14.40		
						0																	.44	-10.52	-3.42	-7.56	3.11	-14.43		

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1		N2		N3		N4		N5		N6		N7		N8		N9		N10		N11		N12	
							-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2
Zero load gage output vs temperature	Gages installed in chamber. Chamber horizontal. Prior to casting.				20(T_6)	0						6.93											3.26	-5.74	-3.39	5.15	5.07	-8.09		
					30(T_6)							6.91											3.75	-5.58	-3.03	5.21	5.29	-		
					20(T_{17})							6.92											3.19	-6.50	-2.95	5.22	5.34	-8.68		
					20(T_4)						.30	5.60	4.08	3.73																
(The signs of the recorded values for N1-1, N1-2, N9-1, and N11-2 have been reversed to show a positive response to an increasing compressive stress. Values for gage N2 were not recorded)	Chamber cooled locally by application of dry ice.				$< 0(T_{16})$																21.01	-49.08								
					20(T_4)						.56	5.77	-4.29	3.76																
					$< 0(T_{16})$																21.69	-49.69								
					45(T_{10})										-3.57	-4.30	-6.17	-2.14	-3.77	1.60										
					$< 0(T_{16})$																.11	-24.03								
					10(T_4)						.71	6.73	-3.76	4.52																
					45(T_{10})										-4.03	-4.84	-6.16	-2.11	-3.75	1.60										
					$< 0(T_{16})$																-1.09	-21.28								
					10(T_4)						.24	7.18	-3.65	4.22																
					44(T_4)						.19	7.53	-2.30	2.16																
					60(T_{11})										-3.95	-4.71	-6.07	-2.11	-4.02	1.47										
					10(T_{16})																-4.65	-8.69								
					44(T_4)						.18	7.52	-2.23	2.09																
					60(T_{11})										-3.96	-4.72	-6.06	-2.11	-4.04	1.47										
					10(T_{16})																-4.66	-8.42								
					60(T_{11})										-4.25	-5.00	-6.39	-2.94	-4.01	1.13										
					60(T_{11})										-4.24	-5.01	-6.38	-2.88	-4.07	1.13										
					40(T_{11})										-3.39	-4.47	-4.97	-.69	-3.49	2.01										
					40(T_{11})										-3.43	-4.55	-5.00	-.76	-3.64	1.93										
					60(T_{20})		-5.74	6.97																						
					60(T_{20})		-5.72	6.97																						
					40(T_{20})		-7.39	5.87																						
					40(T_{20})		-7.38	5.87																						
Zero load gage check (The signs of the recorded values for N1-1, N1-2, N3-2, N4-1, N8-2, and N9-1 have been reversed to show a positive response to an increasing compressive stress)	Chamber in casting bell. Vertical position, supported on forward skirt.	11-2-72			50 ± 5	0	-22.14	-21.34	-19.04	-99.04	-16.94	-13.64	-7.14	-5.34	-8.64	-15.14	-8.64	-6.34	-4.34	3.14	3.24	4.04	-21.14	-23.44	-22.14	-23.04	-20.74	-24.04	-5.54	-3.94
Post cast gage check	Propellant in motor-uncured. Pressure cure (14-16 psig) started 19:45 hours on 11-2-72.	11-3-72	1540	.83*	90	15	-8.95	-4.64	.90	-92.56	-11.91	-6.78	-4.75	-	3.56	-4.60														
							-8.96	-4.65	.91	-92.54	-11.87	-6.78	-4.76	-	3.56	-4.60														
							-8.96	-4.65	.92	-92.54	-11.87	-6.78	-4.76	-	3.56	-4.60														
							-8.99	-4.66	.92	-92.53	-11.85	-6.77	-4.76	-	3.56	-4.60														
(The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)			1615	.85			-9.08	-4.73	.35	-93.06	-11.64	-6.79	-4.79	-.47	3.51	-4.68	.59	3.24	10.11	11.46	14.87	26.72	5.20	-3.72	3.27	-1.46	13.53	-8.76		
																	.59	3.24	10.11	11.46	14.77	26.59	5.20	-3.72	3.27	-1.46	13.54	-8.74		
																	.59	3.23	10.12	11.47	14.77	26.71	5.16	-3.77	3.26	-1.46	13.54	-8.73		
																	.60	3.26	10.17	11.54	14.85	26.70	5.17	-3.76	3.22	-1.53	13.56	-8.71		
Propellant cure cycle	Motor in vertical position in casting bell with 15 psig internal pressure.	11-3-72	1630	.86	90	15	-9.12	-4.76	.47	-92.94	-11.64	-6.75	-4.79	-.49	3.55	-4.68	.59	3.24	10.11	11.46	14.88	26.72	5.20	-3.72	3.27	-1.46	13.54	-8.76	-2.38	.67
		11-6-72	1010	3.4	113		-10.23	-5.64	-2.05	-96.72	-13.30	-13.55	-5.57	-1.82	.41	-7.71	-1.48	1.34	6.91	8.96	11.54	19.49	2.57	-6.41	.40	-3.90	10.86	-10.59	-4.23	-1.04
			1012				-10.23	-5.64	-2.05	-96.72	-13.30	-13.55	-5.57	-1.82	.41	-7.71														
			1014				-10.23	-5.64	-2.04	-96.71	-13.29	-13.56	-5.47	-1.77	.43	-7.70														
	*Elapsed time taken from application of cure pressure.		1016				-10.22	-5.64	-2.05	-96.71	-13.29	-13.58	-5.46	-1.72	.44	-7.69														
			1018				-10.28	-5.72	-2.03	-96.71	-13.29	-13.58	-5.48	-1.77	.44	-7.69														
			1020				-10.23	-5.60	-2.03	-96.70	-13.28	-13.58	-5.38	-1.62	.43	-7.70														
			1040														-1.48	1.34	6.91	8.96	11.54	19.49	2.57	-6.41	.40	-3.90	10.88	-10.59	-4.23	-1.04
			1042														-1.48	1.34	6.95	9.02	11.51	19.47	2.58	-6.42	.40	-3.91	10.88	-10.60	-4.22	-1.01
			1044														-1.47	1.35	6.95	9.01	11.49	19.46	2.58	-6.41	.40	-3.91	10.87	-10.61	-4.22	-1.03
(The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)			1435	3.8			-10.17	-5.53	-1.87	-96.58	-13.89	-14.06	-5.55	-1.83	.75	-7.37														
			1437				-10.14	-5.56	-1.64	-96.54	-13.86	-12.21	-5.56	-1.99	.81	-7.29														
			1439				-10.13	-5.55	-1.64	-96.54	-13.85	-12.21	-5.57	-1.99	.82	-7.28														
			1441				-10.13	-5.55	-1.64	-96.54	-13.85	-12.21	-5.57	-1.99	.82	-7.28														
			1443				-10.14	-5.57	-1.63	-96.53	-13.83	-12.23	-5.59		.82	-7.29														
			1445				-10.13	-5.54	-1.63	-96.53	-13.84	-12.21	-5.59	-2.00	.83	-7.27														
			1445														-1.64	1.08	7.46	9.31	11.74	21.64	2.56	-5.40	.57	-3.87	11.07	-10.59	-4.33	-1.19
																	-1.65	1.07	7.45	9.29	11.73	21.66	2.56	-5.40	.59	-3.86	11.07	-10.60	-4.30	-1.19
																	-1.64	1.08	7.45	9.30	11.75	21.66	2.56	-5.40	.58	-3.86	11.07	-10.60	-4.32	-1.19
																	-1.64	1.08	7.46	9.31	11.75	21.67	2.57	-5.39	.59	-3.85	11.07	-10.60	-4.32	-1.19
																	-1.63	1.09	7.47	9.31	11.75	21.67	2.57	-5.39	.60	-3.85	11.08	-10.59	-4.31	-1.18
																	-1.63	1.08	7.47	9.32	11.75	21.65	2.57	-5.39	.60	-3.84	11.10	-10.57	-4.32	-1.18
																	-1.64	1.07	7.45	9.29	11.75	21.67	2.58	-5.39	.60	-3.84	11.08	-10.59	-4.30	-1.18
																	-1.62	1.10	7.46	9.31	11.77	21.68	2.58	-5.38	.61	-3.84	11.10	-10.57	-4.30	-1.18
																	-1.63	1.09	7.47	9.31	11.76	21.68	2.57	-5.38	.60	3.84	11.08	-10.60	-4.30	-1.18
																	-1.63	1.08	7.46	9.30	11.75	21.68	2.58	-5.38	.60	-3.84	11.08	-10.59	-4.30	-1.18
																	-1.63	1.09	7.47	9.30	11.76	21.69	2.57	-5.39	.61	-3.84	11.08	-10.60	-4.30	-1.18
																	-1.63	1.09	7.47	9.31	11.77	21.70	2.58	-5.38	.61	-3.84	11.06	-10.62	-4.31	-1.18
																	-1.63	1.06	7.48	9.32	11.77	21.68	2.58	-5.38	.61	-3.83	11.08	-10.61	-4.29	-1.18
																	-1.63	1.09	7.47	9.31	11.75	21.70	2.60	-5.35	.61	-3.85	11.07	-10.61	-4.29	-1.16
																	-1.63	1.09	7.48	9.32	11.77	21.70	2.59	-5.38	.61	-3.83	11.08	-10.59	-4.30	-1.18
																	-1.66	1.05	7.48	9.33	11.78	21.71	2.58	-5.37	.61	-3.83	11.09	-10.59	-4.30	-1.18
																	-1.66	1.04	7.48	9.32	11.78	21.71	2.58	-5.37	.61	-3.83	11.09	-10.59	-4.30	-1.18

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	D2M -1	D2M -2
																	-1.63	1.08	7.49	9.33	11.78	21.72	2.58	-6.37	.62	-3.83	11.09	-10.58	-4.30	-1.18
																	-1.62	1.09	7.49	9.33	11.78	21.72	2.58	-6.37	.62	-3.82	11.09	-10.58	-4.30	-1.18
																	-1.62	1.10	7.49	9.34	11.78	21.72	2.59	-6.37	.62	-3.82	11.10	-10.58	-4.30	-1.18
																	-1.61	1.10	7.49	9.34	11.78	21.65	2.58	-6.37	.59	-3.84	11.09	-10.58	-4.30	-1.19
																	-1.62	1.10	7.50	9.34	11.71	21.68	2.59	-6.37	.62	-3.83	11.10	-10.58	-4.30	-1.18
																	-1.62	1.10	7.49	9.34	11.76	21.71	2.56	-6.41	.62	-3.83	11.09	-10.58	-4.29	-1.18
																	-1.61	1.10	7.50	9.34	11.77	21.72	2.58	-6.38	-	-	11.09	-10.59	-4.28	-1.17
																	-1.62	1.10	7.50	9.34	11.77	21.73	2.59	-6.38	.61	-3.85	11.10	-10.58	-4.30	-1.17
																	-1.62	1.11	7.50	9.34	11.78	21.73	2.59	-6.37	.62	-3.83	11.10	-10.58	-4.31	-1.18
																	-1.61	1.11	7.50	9.34	11.78	21.72	2.59	-6.37	.62	-3.83	11.10	10.58	-4.30	-1.18
																	-1.61	1.11	7.51	9.35	11.78	21.74	2.58	-6.38	.62	-3.82	11.10	-10.58	-4.28	-1.17
																	-1.61	1.11	7.52	9.35	11.78	21.74	2.58	-6.37	.62	-3.82	11.10	-10.58	-4.30	-1.17
			1500														-1.61	1.11	7.51	9.35	11.78	21.74	2.58	-6.37	.62	-3.83	11.10	-10.58	-4.29	-1.17
			1500		114		-10.07	-5.50	-1.48	-96.36	-13.75	-10.91	-5.61	-1.79	.98	-7.11	-1.61	1.11	7.51	9.35	11.78	21.75	2.58	-6.37	.62	-3.83	11.10	-10.58	-4.29	-1.17
	Alternate readings listed during this period.		1505	3.9			-10.07	-5.50	-1.48	-96.36	-13.75	-10.91	-5.61	-1.79	.98	-7.12														
							-10.06	-5.49	-1.48	-96.35	-13.74	-10.91	-5.61	-1.75	1.01	-7.09														
							-10.06	-5.49	-1.47	-96.35	-13.73	-10.92	-5.62	-1.75	1.02	-7.09														
							-10.05	-5.49	-1.47	-96.34	-13.73	-10.91	-5.64	-1.77	1.02	-7.08														
							-10.05	-5.48	-1.46	-96.34	-13.73	-10.92	-5.64	-1.73	1.02	-7.08														
							-10.05	-5.49	-1.45	-96.34	-13.72	-10.92	-5.64	-1.75	1.03	-7.08														
							-10.04	-5.47	-1.46	-96.33	-13.72	-10.91	-5.64	-1.75	1.03	-7.07														
							-10.05	5.48	-1.45	-96.33	-13.72	-10.91	-5.63	-1.74	1.04	-7.07														
							-10.04	-5.48	-1.46	-96.34	-13.72	-10.91	-5.64	-1.74	1.04	-7.07														
							-10.04	-5.47	-1.45	-96.33	-13.72	-10.90	-5.75	-1.89	1.04	-7.07														
							-10.04	-5.48	-1.45	-96.33	-13.72	-10.90	-5.64	-1.74	1.04	-7.06														
							-10.09	-5.58	-1.45	-96.33	-13.71	-10.90	-5.64	-1.74	1.05	-7.06														
							-10.05	-5.47	-1.45	-96.33	-13.71	-10.89	-5.65	-1.75	1.02	-7.07														
							-10.04	-5.47	-1.45	-96.32	-13.71	-10.89	-5.63	-1.73	1.04	-7.06														
							-10.04	-5.47	-1.45	-96.33	-13.71	-10.89	-5.64	-1.74	1.04	-7.06														
							-10.04	-5.47	-1.44	-96.33	-13.71	-10.89	-5.65	-1.75	1.05	-7.06														
							-10.04	5.47	-1.44	-96.33	-13.69	-10.88	-5.64	-1.75	1.05	-7.06														
							-10.04	-5.48	-1.44	-96.33	-13.71	-10.88	-5.64	-1.73	1.05	-7.06														
							-10.02	-5.46	-1.44	-96.32	-13.70	-10.87	-5.64	-1.74	1.05	-7.06														
							-10.03	-5.47	-1.44	-96.33	-13.71	-10.87	-5.64	-1.73	1.05	-7.06														
							-10.04	-5.47	-1.45	-96.33	-13.71	-10.87	-5.64	-1.74	1.05	-7.05														
			2000	4.0			-9.99	-5.45	-1.27	-96.20	-13.61	-9.62	-5.62	-1.62	1.23	-6.89														
							-9.96	-5.41	-1.07	-96.19	-13.60	-9.65	-5.62	-1.61	1.23	-6.88														
							-9.95	-5.39	-1.26	-96.19	-13.60	-9.65	-5.62	-1.61	1.24	-6.87														
							-9.95	-5.39	-1.25	-96.19	-13.59	-9.64	-5.63	-1.61	1.25	-6.86														
							-9.95	-5.38	-1.25	-96.19	-13.59	-9.64	-5.60	-1.56	1.25	-6.86														
							-9.95	-5.38	-1.24	-96.18	-13.58	-9.64	-5.64	-1.62	1.25	-6.86														
							-9.94	-5.38	-1.24	-96.19	-13.58	-9.64	-5.63	-1.60	1.26	-6.85														
							-9.94	-5.38	-1.25	-96.19	-13.58	-9.63	-5.63	-1.60	1.26	-6.85														
							-9.94	-5.38	-1.25	-96.19	-13.58	-9.63	-5.64	-1.60	1.26	-6.85														
							-9.94	-5.38	-1.25	-96.18	-13.58	-9.62	-5.70	-1.72	1.26	-6.85														
							-9.94	-5.38	-1.25	-96.17	-13.58	-9.62	-5.64	-1.61	1.27	-6.85														
							-9.94	-5.37	-1.25	-96.17	-13.57	-9.61	-5.64	-1.60	1.28	-6.85														
							-9.95	-5.41	-1.25	-96.17	-13.57	-9.61	-5.63	-1.59	1.26	-6.86														
							-9.94	-5.38	-1.24	-96.16	-13.57	-9.60	-5.63	-1.58	1.26	-6.85														
							-9.94	-5.37	-1.24	-96.17	-13.57	-9.60	-5.63	-1.59	1.27	-6.84														
							-9.93	-5.37	-1.24	-96.17	-13.57	-9.60	-5.64	-1.61	1.27	-6.84														
							-9.94	-5.38	-1.24	-96.16	-13.57	-9.59	-5.64	-1.59	1.28	-6.84														
							-9.94	-5.37	-1.24	-96.16	-13.57	-9.59	-5.64	-1.60	1.28	-6.84														
							-9.93	-5.37	-1.24	-96.17	-13.57	-9.58	-5.63	-1.58	1.28	-6.84														
							-9.93	-5.36	-1.24	-96.17	-13.57	-9.57	-5.63	-1.58	1.29	-6.83														
			2400	4.2			-9.89	-5.31	-1.09	-95.91	-13.50	-8.68	-5.62	-1.53	1.42	-6.70														
							-9.88	-5.32	-1.09	-95.90	-13.49	-8.68	-5.62	-1.52	1.43	-6.69														
							-9.88	-5.31	-1.09	-95.90	-13.48	-8.68	-5.63	-1.52	1.43	-6.69														
							-9.88	-5.31	-1.08	-95.89	-13.48	-8.68	-5.77	-1.71	1.44	-6.69														
							-9.84	-5.28	-1.12	-95.79	-13.43	-8.69	-5.64	-1.47	1.54	-6.59														
							-9.83	-5.27	-1.01	-95.79	-13.43	-8.69	-5.65	-1.47	1.55	-6.59														
							-9.83	-5.27	-1.01	-95.78	-13.42	-8.69	-5.65	-1.46	1.55	-6.58														
							-9.83	-5.27	-1.01	-95.78	-13.42	-	-5.69	-1.52	1.56	-6.57														
							-9.83	-5.26	- .99	-95.77	-13.41	-	-5.65	-1.46	1.57	-6.57														
							-9.87	-5.37	- .99	-95.77	-13.41	-	-5.65	-1.45	1.57	-6.57														
							-9.83	-5.27	- .99	-95.77	-13.41	-	-5.66	-1.45	1.54	-6.58														
							-9.83	-5.25	- .99	-95.77	-13.40	-8.30	-5.65	-1.44	1.56	-6.57														
							-9.83	-5.26	- .99	-95.77	-13.41	-	-5.66	-1.44	1.57	-6.56														
							-9.82	-5.27	- .99	-95.77	-13.39	-8.30	-5.66	-1.45	1.58	-6.56														
							-9.82	-5.25	- .98	-95.76	-13.40	-8.29	-5.67	-1.46	1.58	-6.56														
							-9.82	-5.25	- .98	-95.77	-13.40	-	-5.65	-1.43	1.58	-6.55														
							-9.81	-5.25	- .98	-95.76	-13.40	-8.29	-5.66	-1.44	1.59	-6.55														
							-9.81	-5.24	- .98	-95.76	-13.40	-8.29	-5.66	-1.44	1.59	-6.55														
							-9.82	-5.24	- .99	-95.76	-13.38	-8.31	-5.66	-1.44	1.59	-6.55														
							-9.81	-5.25	- .99	-95.76	-13.40	-8.29	-5.69	-1.49	1.60	-6.54														
							-9.81	-5.24	- .98	-95.76	-13.40	-8.29	-5.66	-1.44	1.60	-6.54														

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	DPM -1	DPM -2
Propellant cure cycle (Cont'd)		11-7-72	0400	4.4		15	-9.86	-5.35	-.98	-95.75	-13.39	-8.29	-5.66	-1.43	1.60	-6.54														
							-9.82	-5.25	-.98	-95.75	-13.39	-8.29	-5.65	-1.43	1.58	-6.54														
							-9.91	-5.24	-.98	-95.75	-13.39	-8.29	-5.56	-1.43	1.60	-6.54														
							-9.81	-5.24	-.98	-95.76	-13.39	-8.28	-5.66	-1.43	1.61	-6.53														
							-9.81	-5.24	-.97	-95.76	-13.38	-8.29	-5.66	-1.44	1.61	-6.53														
							-9.81	-5.24	-.97	-95.74	-13.38	-8.28	-5.67	-1.44	1.61	-6.53														
							-9.80	-5.23	-.97	-95.75	-13.38	-8.29	-5.66	-1.42	1.62	-6.52														
			0800	4.6			-9.63	-5.06	-.82	-95.40	-13.24	-8.07	-5.54	-1.24	2.16	-6.01														
							-9.62	-5.05	-.81	-95.39	-13.23	-8.08	-5.54	-1.24	2.20	-6.00														
							-9.61	-5.03	-.80	-95.39	-13.23	-8.07	-5.55	-1.25	2.19	-5.98														
							-9.61	-5.05	-.79	-95.38	-13.22	-8.08	-5.56	-1.23	2.20	-5.98														
							-9.58	-5.02	-.79	-95.38	-13.23	-8.08	-5.56	-1.23	2.20	-5.98														
							-9.60	-5.03	-.79	-95.38	-13.22	-8.09	-5.59	-1.21	2.20	-5.98														
							-9.60	-5.03	-.79	-95.38	-13.22	-8.09	-5.56	-1.22	2.21	-5.97														
							-0.60	-5.04	-.80	-95.38	-13.22	-8.09	-5.56	-1.21	2.22	-5.96														
							-9.59	-5.02	-.80	-95.37	-13.22	-8.09	-5.69	-1.41	2.22	-5.96														
		11-7-72	0900	4.6	113		-9.65	-5.19	-.78	-95.36	-13.21	-8.09	-5.57	-1.21	2.23	-5.95	-.64	2.04	9.42	10.98	12.87	24.89	3.54	-5.34	1.86	-2.68	12.20	-9.77	-3.85	-.77
							-9.64	-5.14	-.79	-95.37	-13.21	-8.09	-5.56	-1.20	2.23	-5.95	-.62	2.07	9.31	10.82	12.85	24.89	3.55	-5.33	1.87	-2.67	12.24	-9.71	-3.86	-.77
																	-.61	2.08	9.28	10.77	12.85	24.89	3.55	-5.32	1.87	-2.66	12.25	-9.69	-	-
																	-.61	2.08	9.27	10.76	12.85	24.88	3.55	-5.32	1.87	-2.66	12.25	-9.68	-3.84	-.77
																	-.61	2.09	9.26	10.75	12.84	24.80	3.56	-5.32	1.87	-2.66	12.25	-9.68	-3.83	-.77
																	-.60	2.09	9.26	10.75	12.77	24.82	3.55	-5.32	1.87	-2.66	12.26	-9.68	-3.83	-.77
																	-.61	2.09	9.26	10.75	12.81	24.81	3.52	-5.36	1.67	-2.66	12.26	-9.68	-3.83	-.76
																	-.60	2.09	9.27	10.75	12.83	24.87	3.54	-5.33	1.78	-2.80	12.25	-9.68	-3.83	-.77
																	-.60	2.09	9.26	10.74	12.83	24.88	3.55	-5.32	1.86	-2.69	12.26	-9.68	-3.83	-.76
																	-.60	2.10	9.26	10.74	12.84	24.88	3.56	-5.32	1.87	-2.66	12.26	-9.67	-3.88	-.77
																	-.60	2.10	9.26	10.74	12.87	24.88	3.54	-5.31	1.88	-2.66	12.26	-9.67	-3.83	-.76
			1300	4.7	113		-9.43	-4.86	-.61	-95.06	-13.08	-7.93	-5.42	-.99	2.72	-5.48														
							-9.43	-4.87	-.62	-95.06	-13.08	-7.93	-5.42	-.98	2.72	-5.48														
							-9.44	-4.86	-.61	-95.07	-13.08	-7.93	-5.42	-.98	2.73	-5.48														
							-9.43	-4.87	-.62	-95.07	-13.08	-7.93	-5.42	-.99	2.73	-5.48														
							-9.44	-4.87	-.63	-95.07	-13.08	-7.93	-5.42	-.99	2.73	-5.48														
							-9.43	-4.86	-.62	-95.07	-13.08	-7.93	-5.42	-.99	2.73	-5.48														
							-9.43	-4.86	-.62	-95.07	-13.08	-7.93	-5.55	-1.19	2.73	-5.48	-.11	2.58	9.75	-	13.31	25.42	4.03	-4.84	2.35	-2.20	12.70	-9.28	-3.63	-.59
																	-.11	2.59	9.77	-	13.32	25.42	4.02	-4.85	2.35	-2.20	12.71	-9.26	-3.64	-.59
																	-.11	2.59	9.78	-	13.32	25.43	4.02	-4.85	2.35	-2.19	12.72	-9.25	-3.64	-.59
																	-.12	2.58	9.79	-	13.33	25.42	4.02	-4.85	2.35	-2.20	12.72	-9.25	-3.64	-.59
																	-.11	2.59	9.77	-	13.32	25.42	4.02	-4.85	2.35	-2.20	12.71	-9.26	-3.64	-.59
																	-.11	2.59	9.78	-	13.32	25.43	4.02	-4.85	2.35	-2.19	12.72	-9.25	-3.64	-.59
																	-.12	2.58	9.79	-	13.33	25.42	4.02	-4.85	2.35	-2.20	12.72	-9.25	-3.64	-.59
																	-.16	2.51	9.79	-	13.33	25.43	4.02	-4.85	2.35	-2.20	12.72	-9.24	-3.64	-.59
																	-.14	2.54	9.78	-	13.33	25.43	4.02	-4.85	2.35	-2.19	12.72	-9.24	-3.64	-.59
																	-.11	2.57	9.79	-	13.33	25.43	4.02	-4.84	2.35	-2.19	12.72	-9.24	-3.64	-.58
																	-.11	2.59	9.80	-	13.33	25.43	4.03	-4.84	2.35	-2.19	12.72	-9.24	-3.63	-.59
																	-.10	2.59	9.80	-	13.33	25.43	4.03	-4.84	2.35	-2.20	12.72	-9.24	-3.63	-.59
																	-.10	2.60	9.80	-	13.31	25.33	4.03	-4.84	2.35	-2.20	12.73	-9.24	-3.64	-.59
																	-.10	2.60	9.80	-	13.25	25.39	4.01	-4.88	2.35	-2.20	12.72	-9.24	-3.63	-.59
																	-.10	2.60	9.80	-	13.30	25.42	4.00	-4.88	2.28	-2.31	12.72	-9.25	-3.63	-.59
																	-.09	2.60	9.80	-	13.32	25.42	4.02	-4.85	2.29	-2.29	12.72	-9.24	-3.63	-.59
																	-.10	2.60	9.81	-	13.32	25.43	4.02	-4.85	2.34	-2.21	12.73	-9.24	-3.62	-.59
																	-.09	2.61	9.81	-	13.33	25.43	4.03	-4.84	2.35	-2.20	12.73	-9.23	-3.63	-.59
																	-.09	2.61	9.81	-	13.33	25.43	4.03	-4.84	2.35	-2.19	12.73	-9.23	-3.63	-.59
																	-.10	2.60	9.82	-	13.33	25.43	4.04	-4.84	2.36	-2.19	12.73	-9.23	-3.62	-.59
																	-.09	2.61	9.81	-	13.33	25.44	4.03	-4.84	2.35	-2.19	12.73	-9.24	-3.63	-.59
																	-.09	2.61	9.82	-	13.34	25.44	4.03	-4.84	2.36	-2.19	12.73	-9.23	-3.63	-.59
			1610	4.8	112		-9.33	-4.80	-.55	-94.56	-13.09	-7.83	-5.34	-.90	3.02	-5.19														
							-9.33	-4.79	-.55	-94.55	-13.09	-7.82	-5.48	-1.11	3.02	-5.20	.17	2.85	.06	11.46	13.61	25.73	4.33	-4.54	2.66	-1.90	13.02	-8.96	-3.64	-.55
	Alternate readings listed during this period.	11-7-72	2010	5.0			-9.41	-4.95	-.55	-94.29	-13.12	-7.77	-5.31	-.93	3.05	-5.17														
							-9.35	-4.81	-.54	-94.28	-	-	-5.32	-.94	3.02	-														
							-9.34	-4.80	-.53	-94.27	-	-7.78	-5.32	-.91	3.06	-5.16														
							-9.33	-4.80	-.53	-94.27	-	-7.78	-5.32	-.92	3.07	-5.15														
							-9.33	-4.79	-.52	-94.26	-	-	-5.34	-.93	3.07	-5.15														
			2400	5.2			-9.22	-4.65	-.34	-93.67	-13.19	-7.66	-5.23	-.80	3.42	-4.82														
							-9.20	-4.65	-.33	-93.66	-13.18	-7.67	-5.24	.80	3.43	-4.81														
							-9.20	-4.64	-.33	-93.66	-13.17	-7.68	-5.25	-.80	3.44	-4.81														
							-9.19	-4.64	-.32	-93.66	-13.17	-7.68	-5.32	-.92	3.44	-4.81														
							-9.19	-4.65	-.33	-93.66	-13.17	-7.68	-5.26	-.81	3.45	-4.80														
							-9.18	-4.63	-.32	-93.64	-13.16	-7.68	-5.26	-.79	3.46	-4.80														
							-9.21	-4.67	-.32	-93.64	-13.16	-7.68	-5.25	-.78	3.43	-4.81														
							-9.20	-4.64	-.31	-93.64	-13.16	-7.68	-5.25	-.77	3.44	-4.79														
							-9.19	-4.63	-.32	-93.64	-13.16	-7.68	-5.25	-.78	3.45	-4.79														
							-9.18	-4.63	-.32	-93.64	-13.15	-7.68	-5.27	.79	3.46	-4.79														
							-9.19	-4.64	-.31	-93.64	-13.16	-7.68	-5.26	-.78	3.46	-4.78														
							-9.17	-4.60	-.30	-93.63	-13.16	-7.68	-5.28	-.76	3.47	-4.79														
							-9.19	-4.62	-.31	-93.63	-13.16	-7.68	-5.25	-.77	3.47	-4.78														
							-9.18	-4.63	-.31	-93.64	-13.16	-7.68	-5.25	.77	3.47	-4.78														
		11-8-72	0400	5.3			-9.13	-4.57	-.26	-93.47	-13.22	-7.61	-5.19	-.72	3.64	-4.63														
							-8.97	-4.40	.00	-93.07	-13.13	-7.53	-5.05	-.52	4.01	-4.28														
							-9.02	-4.53	.00	-93.07	-13.12	-7.53	-5.06	-.51	4.01	-4.28														
							-8.98	-4.39	.01	-93.06	-13.12	-7.54	-5.07	-.49	3.98	-4.29														
							-8.96	-4.38	.01	-93.06	-13.11	-7.53	-5.06	-.50	4.01	-4.28														
							-8.96	-4.38	.01	-93.05	-13.11	-7.54	-5.06	-.50	4.03	-4.26														
							-8.96	-4.38	.01	-93.05	-13.10	-7.54	-5.06	-.50	4.03	-4.26														

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	[illegible] -1	[illegible] -2
Propellant cure cycle (cont'd)							-8.93	-4.36	.02	-93.02	-13.09	-7.54	-5.07	- .48	4.05	-4.24														
							-8.99	-4.48	.02	-93.03	-13.10	-7.54	-5.06	- .48	4.05	-4.24														
							-8.95	-4.37	.02	-93.02	-13.10	-7.54	-5.06	- .47	4.02	-4.25														
							-8.95	-4.36	.02	-93.03	-13.09	-7.54	-5.06	- .47	4.04	-4.25														
							-8.94	-4.36	.01	-93.03	-13.10	-7.54	-5.06	- .48	4.05	-4.24														
							-8.95	-4.36	.02	-93.03	-13.09	-7.54	-5.06	- .48	4.05	-4.24														
			0800	5.5			-8.90	-4.43	.10	-92.87	-13.04	-7.43	-4.90	- .31	4.38	-3.94														
							-8.82	-4.22	.11	-92.86	-13.03	-7.44	-4.90	- .31	4.34	-3.96														
							-8.80	-4.20	.11	-92.86	-13.03	-7.44	-4.90	- .29	4.38	-3.94														
							-8.80	-4.20	.11	-92.86	-13.02	-7.45	-4.91	- .29	4.39	-3.92														
							-8.80	-4.19	.12	-92.85	-13.02	-7.45	-4.92	- .30	4.40	-3.92														
							-8.80	-4.19	.13	-92.85	-13.02	-7.45	-4.92	- .29	4.40	-3.92														
							-8.79	-4.19	.13	-92.85	-13.02	-7.45	-4.91	- .28	4.41	-3.91														
							-8.79	-4.18	.12	-92.86	-13.01	-7.45	-4.91	- .28	4.41	-3.91														
							-8.79	-4.18	.12	-92.86	-13.01	-7.45	-4.91	- .28	4.41	-3.91														
							-8.79	-4.18	.12	-92.86	-13.01	-7.45	-4.91	- .28	4.42	-3.90														
							-8.79	-4.18	.13	-92.85	-13.01	-7.45	-4.99	- .39	4.42	-3.91														
							-8.79	-4.18	.13	-92.85	-13.01	-7.45	-4.91	- .28	4.42	-3.90														
							-8.87	-4.40	.13	-92.84	-13.01	-7.45	-4.91	- .27	4.43	-3.90														
							-8.80	-4.20	.13	-92.85	-13.01	-7.45	-4.91	- .27	4.39	-3.92														
							-8.79	-4.19	.13	-92.84	-13.00	-7.46	-4.91	- .27	4.42	-3.90														
							-8.79	-4.19	.12	-92.85	-13.01	-7.45	-4.91	- .27	4.42	-3.90														
							-8.79	-4.18	.13	-92.84	-13.01	-7.45	-4.91	- .28	4.42	-3.90														
							-8.78	-4.18	.14	-92.84	-13.00	-7.46	-4.90	- .26	4.43	-3.90														
							-8.78	-4.18	.14	-92.83	-13.00	-7.44	-4.91	- .24	4.43	-3.89														
		11-8-72	0900	5.6	113	15	-8.73	-4.13	.14	-92.75	-13.01	-7.37	-4.83	- .23	4.60	-3.73	1.79	4.49	11.76	13.13	15.11	27.50	5.86	-2.97	4.32	- .22	14.65	-7.34	-3.11	- .06
							-8.73	-4.12	.15	-92.75	-13.00	-7.37	-4.82	- .21	4.60	-3.72	1.80	4.50	11.79	13.17	15.12	27.50	5.86	-2.97	4.33	- .22	14.65	-7.35	-3.11	- .06
							-8.73	-4.13	.13	-92.70	-13.00	-7.37	-4.83	- .23	4.60	-3.73	1.79	4.49	11.78	13.13	15.11	27.50	5.86	-2.97	4.32	- .22	14.65	-7.34	-3.11	- .06
			1300	5.7	113		-8.63	-4.00	.12	-92.41	-12.96	-7.34	-4.96	- .38	4.90	-3.45	2.06	4.78	12.27	13.71	15.40	27.77	6.11	-2.72	4.57	.01	14.96	-6.98	-3.04	.02
							-8.65	-4.05	.14	-92.41	-12.96	-7.33	-4.78	- .13	4.88	-3.46	2.07	4.76	12.29	13.74	15.40	27.77	6.11	-2.72	4.56	.00	14.97	-7.00	-3.04	.02
			1400	5.8			-8.65	-4.11	.12	-92.43	-12.96	-7.30	-4.81	- .18	4.88	-3.44														
			1615	5.9	113		-8.64	-4.05	.07	-92.52	-12.96	-7.25	-4.80	- .26	5.01	-3.34	2.17	4.82	12.16	13.48	15.52	27.91	6.26	-2.58	4.69	.12	15.06	-6.94	-3.09	- .02
							-8.69	-4.16	.09	-92.51	-12.96	-7.25	-4.80	- .26	-	-3.33	2.19	4.85	12.19	13.51	15.52	27.91	6.26	-2.58	4.69	.12	15.06	-6.95	-3.09	- .01
	Alternate readings listed during this period.		2000	6.0			-8.63	-4.06	.09	-92.56	-12.95	-7.24	-4.76	- .19	5.07	-3.28														
							-8.62	-4.06	.10	-92.56	-12.95	-7.25	-4.77	- .19	5.08	-3.28														
							-8.61	-4.04	.11	-92.56	-12.94	-7.25	-4.78	- .19	5.08	-3.27														
							-8.61	-4.05	-	-92.57	-12.93	-7.25	-4.78	- .23	5.09	-3.26														
							-8.61	-4.06	-	-92.57	-12.94	-7.26	-4.79	- .20	5.10	-3.26														
							-8.61	-4.04	.12	-92.57	-12.93	-7.26	-4.79	- .19	5.09	-3.25														
							-8.62	-4.06	-	-92.57	-12.93	-7.26	-4.79	- .18	5.08	-3.27														
							-8.61	-4.04	-	-92.56	-12.93	-7.2-	-4.78	- .17	5.08	-3.26														
							-8.60	-4.03	.13	-92.57	-12.93	-7.26	-4.79	.18	5.09	-3.25														
			2400	6.2			-8.49	-3.87	.18	-92.71	-12.92	-7.20	-4.66	- .05	5.35	-3.02														
							-8.49	-3.87	.19	-92.69	-12.92	-7.20	-4.66	- .03	5.36	-3.02														
							-8.49	-3.87	.20	-92.69	-12.91	-7.21	-4.66	- .03	5.37	-3.01														
							-8.48	-3.86	.20	-92.69	-12.91	-7.21	-4.81	- .24	5.37	-3.01														
							-8.48	-3.86	.21	-92.68	-12.90	-7.21	-4.67	- .03	5.38	-3.00														
							-8.55	-4.04	.21	-92.69	-12.90	-7.21	-4.67	- .02	5.38	-3.00														
							-8.38	-3.74	.28	-92.94	-12.93	-7.16	-4.53	.13	5.53	-2.86														
							-8.38	-3.73	.30	-92.93	-12.90	-7.16	-4.68	- .08	5.54	-2.85														
		11-9-72	0400	6.3			-8.33	-3.68	.34	-93.11	-12.92	-7.14	-4.49	.21	5.61	-2.79														
							-8.33	-3.67	.35	-93.11	-12.92	-7.14	-4.50	.21	5.62	-2.78														
							-8.32	-3.67	.35	-93.12	-12.91	-7.14	-4.50	.22	5.62	-2.78														
							-8.32	-3.67	.36	-93.11	-12.91	-7.15	-4.57	.13	5.63	-2.77														
							-8.32	-3.66	.37	-93.11	-12.91	-7.15	-4.51	.22	5.64	-2.77														
							-8.38	-3.85	.37	-93.11	-12.91	-7.15	-4.51	.23	5.64	-2.77														
							-8.33	-3.68	.37	-93.11	-12.90	-7.16	-4.51	.23	5.61	-2.77														
							-8.32	-3.66	.37	-93.09	-12.90	-7.16	-4.51	.24	5.63	-2.77														
							-8.32	-3.66	.37	-93.10	-12.90	-7.15	-4.51	.23	5.63	-2.76														
							-8.32	-3.66	.37	-93.10	-12.90	-7.16	-4.52	.23	5.64	-2.76														
			0800	6.5			-8.31	-3.66	.39	-93.09	-12.90	-7.16	-4.52	.22	5.64	-2.76														
							-8.31	-3.66	.38	-93.10	-12.90	-7.16	-4.50	.25	5.65	-2.76														
							-8.31	-3.65	.37	-93.11	-12.90	-7.16	-4.51	.24	5.65	-2.75														
							-8.31	-3.65	.37	-93.11	-12.90	-7.16	-4.51	.24	5.65	-2.75														
							-8.31	-3.65	.37	-93.11	-12.90	-7.16	-4.51	.24	5.65	-2.75														
							-8.31	-3.66	.37	-93.11	-12.90	-7.16	-4.55	.17	5.65	-2.75														
							-8.31	-3.65	.38	-93.11	-12.90	-7.16	-4.51	.23	5.65	-2.75														
							-8.38	-3.82	.38	-93.11	-12.89	-7.16	-4.51	.24	5.65	-2.75														
							-8.33	-3.67	.38	-93.11	-12.89	-7.16	-4.50	.25	5.62	-2.76														
		11-9-72	1100	6.6	113	15	-8.23	-3.61	.36	-93.88	-12.89	-7.06	-4.41	.27	5.89	-2.52	3.14	5.83	13.17	14.50	16.43	28.85	7.14	-1.66	5.66	1.12	15.98	-6.06	-2.71	.31
							-8.23	-3.60	.37	-93.87	-12.88	-7.06	-4.56	.06	5.90	-2.51	3.14	5.84	13.19	14.53	16.44	28.85	7.15	-1.65	5.67	1.11	15.97	-6.07	-2.71	.32
			1610	6.9			-8.15	-3.50	.67	-93.96	-12.90	-7.06	-4.52	.11	5.94	-2.46	3.18	5.86	-	14.51	16.42	28.78	7.31	-1.48	5.83	1.27	16.19	-5.81	-2.88	.20
							-8.14	-3.49	.67	-93.95	-12.91	-7.04	-4.52	.11	5.96	-2.45	3.19	5.87	-	14.50	16.40	28.83	7.28	-1.51	5.86	1.31	16.21	-5.82	-2.89	.20
							-8.14	-3.49	.67	-93.95	-12.91	-7.04	-4.53	.11	5.97	-2.44	3.20	5.88	-	14.51	16.46	28.85	7.30	-1.50	5.75	1.16	16.20	-5.79	-2.97	.20

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N-1 -1	N-1 -2	N-2 -1	N-2 -2	N-3 -1	N-3 -2	N-4 -1	N-4 -2	N-5 -1	N-5 -2	N-6 -1	N-6 -2	N-7 -1	N-7 -2	N-8 -1	N-8 -2	N-9 -1	N-9 -2	N-10 -1	N-10 -2	N11 -1	N11 -2	D2N -1	D2N -2
Propellant Cure Cycle (cont'd)	Alternate readings listed during this period.		2000	7.0			-8.12	-3.49	.70	-93.92	-12.90	-7.05	-4.54	.13	5.99	-2.42														
							-8.14	-3.50	.68	-93.94	-12.91	-7.04	-4.53	.10	5.94	-2.45														
							-8.13	-3.48	.68	-93.94	-12.90	-7.04	-4.52	.13	5.98	-2.43														
							-8.13	-3.48	.68	-93.94	-12.89	-7.05	-4.53	.12	5.99	-2.42														
							-8.12	-3.47	.69	-93.93	-12.89	-7.05	-4.54	.11	5.99	-2.42														
							-8.11	-3.48	.69	-93.92	-12.89	-7.05	-4.54	.12	6.00	-2.42														
							-8.12	-3.48	.70	-93.92	-12.89	-7.05	-4.53	.13	6.00	-2.41														
							-8.11	-3.46	.69	-93.92	-12.89	-7.05	-4.54	.12	6.00	-2.41														
							-8.11	-3.47	.69	-93.92	-12.88	-7.06	-4.54	.13	6.00	-2.41														
							-8.11	-3.47	.68	-93.92	-12.88	-7.06	-4.54	.13	6.01	-2.41														
			2400	7.2			-8.16	-3.40	.75	-93.73	-12.86	-6.99	-4.48	.17	6.15	-2.28														
							-	-3.39	.77	-93.72	-12.86	-7.00	-4.59	.03	6.15	-2.28														
							-	-3.39	.78	-93.70	-12.85	-7.00	-4.49	.17	6.16	-2.27														
							-8.11	-3.58	.78	-93.70	-12.85	-7.01	-4.49	.18	6.16	-2.27														
							-8.15	-3.39	.79	-93.69	-12.84	-7.01	-4.50	.19	6.13	-2.28														
							-8.04	-3.38	.79	-93.68	-12.84	-7.01	-4.49	.20	6.16	-2.27														
							-8.03	-3.37	.79	-93.68	-12.84	-7.01	-4.50	.20	6.17	-2.26														
							-8.03	-3.37	.79	-93.68	-12.84	-7.01	-4.51	.18	6.17	-2.26														
							-8.03	-3.37	.80	-93.67	-12.84	-7.01	-4.51	.19	6.17	-2.26														
							-8.03	-3.38	.80	-93.67	-12.83	-7.01	-4.50	.20	6.17	-2.26														
							-8.02	-3.37	.80	-93.67	-12.83	-7.01	-4.51	.19	6.17	2.26														
		11-10-72	0400	7.3			-7.95	-3.28	.93	-93.24	-12.75	-6.94	-4.41	.30	6.36	-2.09														
							-7.95	-3.27	.94	-93.24	-12.74	-6.95	-4.42	.29	6.37	-2.08														
							-7.94	-3.28	.96	-93.22	-12.74	-6.95	-4.42	.30	6.37	-2.08														
							-7.94	-3.27	.96	-93.22	-12.74	-	-4.42	.32	6.37	-2.07														
							-7.93	-3.26	.95	-93.22	-12.73	-	-4.43	.31	6.38	-2.07														
							-7.93	-3.26	.95	-93.23	-12.73	-	-4.43	.32	6.38	-2.06														
		11-10-72	0840	7.5	114	15	-7.94	-3.28	.93	-93.21	-12.76	-	-4.41	.29	6.39	-2.05	3.67	6.33	13.76	15.01	16.90	29.38	7.75	-1.03	6.36	1.75	16.65	-5.34	-2.84	.28
							-7.94	-3.28	.94	-93.21	-12.75	-	-4.41	.30	6.39	-2.05	3.69	6.35	13.70	15.05	16.97	29.40	7.75	-1.04	6.28	1.74	16.67	-5.32	-2.80	.30
			0855	7.5			-7.93	-3.27	.93	-93.24	-12.76	-6.86	-4.53	.11	6.42	-2.03														
							-7.92	-3.26	.93	-93.24	-12.75	-6.86	-4.42	.29	6.43	-2.02														
							-7.92	-3.26	.94	-93.23	-	-6.87	-4.42	.30	6.43	-2.02														
	Alternate readings listed during this period.		1100	7.6			-7.99	-3.45	.94	-93.24	-12.74	-6.87	-4.42	.31	6.43	-2.02														
							-7.91	-3.27	.96	-93.24	-12.74	-6.86	-4.40	.29	6.39	-2.01														
							-7.92	-3.26	.95	-93.23	-12.74	-6.88	-4.45	.35	6.41	-2.05														
							-7.92	-3.25	.95	-93.22	-12.74	-6.87	-4.41	.33	6.43	-2.01														
							-7.88	-3.26	.95	-93.22	-12.73	-6.87	-4.43	.31	6.44	-2.00														
							-7.91	-3.25	.97	-93.22	-12.73	-6.87	-4.42	.33	6.44	-2.00														
			1300	7.7			-7.79	-3.13	1.08	-93.40	-12.68	-6.64	-4.31	.44	6.75	-1.72														
							-7.79	-3.13	1.08	-93.39	-12.67	-6.65	-4.34	.39	6.76	-1.71														
							-7.78	-3.12	1.10	-93.38	-12.66	-6.65	-4.32	.44	6.77	-1.70														
							-7.82	-3.23	1.10	-93.39	-12.66	-6.65	-4.32	.45	6.77	-1.71														
							-7.78	-3.13	1.10	-93.38	-12.66	-6.66	-4.32	.46	6.74	-1.72														
							-7.77	-3.11	1.10	-93.38	-12.66	-6.66	-4.32	.46	6.77	-1.70														
		11-10-72	1500	7.8	114		-7.75	-3.08	1.12	-93.40	-12.63	-6.60	-4.26	.49	6.85	-1.62	4.11	6.75	14.30	15.55	17.38	30.22	8.16	- .61	6.84	2.28	17.16	-4.89	-2.73	.33
							-7.74	-3.07	1.11	-93.40	-12.62	-6.60	-4.26	.49	6.88	-1.60	4.11	6.75	14.30	15.55	17.43	30.25	8.19	- .58	6.82	2.26	17.18	-4.89	-2.74	.34
	Alternate readings listed during this period.		1600	7.8			-7.72	-3.05	1.16	-93.33	-12.61	-6.58	-4.25	.51	6.93	-1.56														
							-7.71	-3.04	1.17	-93.32	-12.60	-6.58	-4.26	.52	6.94	-1.55														
							-7.71	-3.04	1.17	-93.30	-12.60	-6.59	-4.28	.48	6.94	-1.54														
							-7.70	-3.03	1.18	-93.30	-12.60	-6.59	-4.26	.52	6.95	-1.54														
							-7.74	-3.12	1.18	-93.28	-12.59	-6.59	-4.26	.53	6.95	-1.54														
							-7.70	-3.04	1.19	-93.27	-12.59	-6.59	-4.26	.54	6.93	-1.54														
							-7.70	-3.02	1.19	-93.27	-12.58	-6.60	-4.26	.54	6.95	-1.53														
							-7.69	-3.02	1.19	-93.27	-12.58	-6.60	-4.26	.54	6.96	-1.50														
							-7.69	-3.02	1.19	-93.26	-12.58	-6.60	-4.27	.54	6.96	-1.52														
							-7.69	-3.02	1.20	-93.26	-12.58	-6.59	-4.27	.54	6.97	-1.52														
							-7.69	-3.02	1.19	-93.26	-12.58	-6.59	-4.26	.55	6.97	-1.52														
			2000	8.0			-7.58	-2.90	1.30	-93.71	-12.47	-6.50	-4.13	.65	7.24	-1.27														
							-7.58	-2.90	1.29	-93.72	-12.46	-6.51	-4.15	.65	7.25	-1.26														
							-7.57	-2.89	1.30	-93.72	-12.46	-6.51	-4.15	.66	7.25	-1.26														
							-7.57	-2.89	1.30	-93.72	-12.46	-6.51	-4.15	.67	7.26	-1.25														
							-7.57	-2.89	1.30	-93.71	-12.46	-6.51	-4.18	.63	7.26	-1.25														
							-7.56	-2.88	1.31	-93.71	-12.45	-6.51	-4.16	.66	7.26	-1.24														
							-7.59	-	1.31	-93.70	-12.45	-6.52	-4.16	.67	7.28	-1.25														
							-7.57	-2.89	1.31	-93.70	-12.45	-6.52	-4.16	.68	7.24	-1.25														
							-7.57	-2.88	1.31	-93.71	-12.45	-6.52	-4.16	.68	7.26	-1.24														
							-7.56	-2.88	1.31	-93.71	-12.45	-6.52	-4.16	.68	7.26	-1.24														
							-7.56	-2.88	1.32	-93.71	-12.45	-6.52	-4.16	.68	7.27	-1.24														
							-7.56	-2.88	1.32	-93.71	-12.45	-6.52	-4.17	.67	7.27	-1.24														
			2400	8.2			-7.29	-2.58	2.08	-93.24	-12.06	-6.41	-3.89	1.03	7.80	- .75														
							-7.29	-2.57	2.08	-93.23	-	6.41	-3.89	1.04	7.81	- .74														
							-7.28	-2.57	2.10	-93.22	-12.05	-6.42	-3.90	1.03	7.81	- .73														
							-7.28	-2.56	2.10	-93.22	-12.04	-6.42	-3.90	1.04	7.82	- .73														

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	D2N -1	D2N -2
Propellant cure cycle (cont'd)		11-11-72	0400	8.3			-7.15	-2.40	2.41	-92.97	-11.72	-6.44	-3.76	1.19	8.07	-.51														
							-7.14	-2.39	2.41	-92.97	-11.71	-6.45	-3.76	1.19	8.07	-.50														
							-7.13	-2.38	2.42	-92 96	-11.71	-6.45	-3.77	1.20	8.08	-.50														
							-7.13	-2.38	2.42	-92.96	-11.70	-6.46	-3.78	1.21	8.08	-.49														
							-7.12	-2.37	2.43	-92.96	-11.70	-6.47	-3.81	1.15	8.09	-.48														
							-7.13	-2.38	2.42	-92.95	-11.70	-6.47	-3.79	1.19	8.09	-.49														
							-7.12	-2.38	2.42	-92.95	-11.70	-6.47	-3.78	1.21	8.08	-.49														
							-7.13	-2.40	2.43	-92.94	-11.69	-6.48	-3.78	1.21	8.08	-.49														
							-7.12	-2.38	2.43	-92.94	-11.69	-6.48	-3.78	1.22	8.07	-.49														
			0800	8.5			-7.06	-2.31	2.62	-92.80	-11.59	-6.32	-3.71	1.27	8.23	-.37														
							-7.05	-2.32	2.58	-92.78	-11.58	-6.33	-3.71	1.27	8.21	-.35														
							-7.04	-2.30	2.67	-92.78	-11.58	-6.32	-3.67	1.30	8.25	-.34														
							-7.04	-2.30	2.63	-92.79	-11.57	-6.34	-3.73	1.30	8.25	-.33														
							-7.04	-2.29	2.63	-92.80	-11.57	-6.34	-3.77	1.23	8.25	-.33														
							-7.04	-2.30	2.63	-92.80	-11.57	-6.34	-3.74	1.28	8.25	-.33														
			1200	8.7			-7.10	-2.46	1.92	-93.58	-11.74	-6.25	-3.81	1.11	8.39	-.19														
							-7.08	-2.45	1.91	-93.58	-11.73	-6.27	-3.81	1.09	8.36	-.17														
							-7.09	-2.44	1.94	-93.54	-11.73	-6.28	-3.82	1.12	8.40	-.17														
							-7.09	-2.44	1.94	-93.56	-11.73	-6.28	-3.83	1.12	8.40	-.17														
							-7.08	-2.44	1.93	-93.57	-11.73	-6.28	-3.83	1.11	-	-.17														
							-7.08	-2.43	1.93	-93.58	-11.73	-6.28	-3.83	1.11	8.41	-.16														
							-7.08	-2.44	1.92	-93.58	-11.73	-6.28	-3.83	1.11	8.40	-.16														
							-7.08	-2.43	1.92	-93.58	-11.73	-6.28	-3.92	.99	8.41	-.16														
							-7.07	-2.43	1.92	-93.57	-11.72	-6.28	-3.84	1.11	8.41	-.16														
							-7.15	-2.61	1.92	-93.58	-11.73	-6.28	-3.84	1.12	8.41	-.16														
			1600	8.8			-7.07	-2.40	1.93	-93.71	-11.84	-6.24	-3.79	1.12	8.51	-.07														
							-7.06	-2.40	1.93	-93.72	-11.84	-6.25	-3.79	1.13	8.52	-.07														
							-7.06	-2.40	1.93	-93.72	-11.83	-6.25	-3.79	1.14	8.53	-.07														
							-7.06	-2.38	1.94	-93.71	-11.83	-6.25	-3.89	1.02	8.52	-.06														
							-7.05	-2.38	1.95	-93.71	-11.83	-6.26	-3.81	1.13	8.53	-.05														
							-7.12	-2.56	1.95	-93.72	-11.84	-6.26	-3.81	1.15	8.54	-.04														
							-7.06	-2.40	1.96	-93.70	-11.83	-6.26	-3.81	1.15	8.50	-.07														
							-7.05	-2.38	1.96	-93.70	-11.82	-6.26	-3.80	1.16	8.53	-.07														
							-7.04	-2.38	1.95	-93.70	-11.82	-6.25	-3.81	1.16	8.53	-.04														
							-7.04	-2.37	1.96	-93.70	-11.82	-6.26	-3.81	1.15	8.54	-.04														
							-7.04	-2.37	1.97	-93.70	-11.82	-6.26	-3.81	1.16	8.55	-.05														
							-7.05	-2.40	1.95	-93.70	-11.82	-6.29	-3.82	1.14	8.53	-.04														
							-7.05	-2.39	1.98	-93.69	-11.83	-6.25	-3.82	1.13	8.59	.03														
			2000	9.0			-6.76	-2.02	2.61	-93.35	-11.68	-6.16	-3.49	1.65	9.12	.45														
							-6.75	-2.03	2.66	-93.32	-11.61	-6.19	-3.50	1.61	9.09	.47														
							-6.77	-2.03	2.64	-93.32	-11.65	-6.17	-3.49	1.63	9.13	.48														
							-6.73	-2.01	2.66	-93.30	-11.64	-6.17	-3.50	1.64	9.13	.48														
							-6.74	-2.01	2.65	-93.31	-11.64	-6.17	-3.50	1.63	9.12	.48														
							-6.73	-1.99	2.65	-93.32	-11.66	-6.18	-3.55	1.62	9.11	.48														
			2400	9.2			-6.62	-1.88	2.92	-93.34	-11.53	-6.12	-3.38	1.76	9.34	.68														
							-6.56	-1.92	2.92	-93.34	-11.52	-6.11	-3.38	1.75	9.35	.74														
							-6.62	-	2.90	-93.35	-11.52	-6.14	-3.38	1.84	9.32	.66														
							-6.58	-1.87	2.93	-93.33	-11.50	-6.13	-3.38	1.78	9.34	.68														
							-6.60	-1.87	2.91	-93.33	-11.51	-6.13	-3.38	1.77	9.35	.70														
							-6.60	-1.86	2.94	-93.31	-11.50	-6.14	-3.39	1.78	9.36	.69														
							-6.60	-1.86	2.94	-93.33	-11.49	-6.14	-3.39	1.79	9.36	.70														
							-6.50	-1.86	2.95	-93.31	-11.49	-6.14	-3.39	1.79	9.36	.70														
							-6.60	-1.86	2.94	-93.32	-11.49	-6.14	-3.39	1.79	9.37	.70														
		11-12-72	0400	9.3			-6.50	-1.76	3.22	-93.27	-11.34	-6.09	-3.28	1.86	9.57	.88														
							-6.51	-1.78	3.27	-93.25	-11.38	-	-3.32	1.88	9.55	.86														
							-6.46	-1.76	3.21	-93.22	-11.35	-6.09	-3.27	1.89	9.58	.89														
							-6.48	-1.74	3.23	-93.28	-11.34	-6.12	-3.33	1.83	9.54	.89														
							-6.49	-1.75	3.22	-93.25	-11.33	-6.10	-3.30	1.88	9.56	.87														
							-6.50	-1.77	3.27	-93.23	-11.35	-6.10	-3.27	1.91	9.58	.87														
			0800	9.5			-6.55	-1.81	3.02	-93.19	-11.34	-6.08	-3.31	1.81	9.60	.93														
							-6.53	-	3.06	-93.24	-11.37	-6.09	-3.32	1.82	9.62	.94														
							-6.48	-1.77	3.02	-93.22	-11.36	-6.08	-3.33	1.81	9.61	.90														
							-6.53	-1.76	3.08	-93.18	-11.38	-6.06	-3.32	1.87	9.64	.96														
							-6.50	-1.78	3.02	-93.20	-11.36	-6.07	-3.34	1.84	9.62	.94														
							-6.51	-1.77	3.06	-93.22	-11.38	-6.12	-3.39	1.83	9.62	.93														
							-6.43	-1.76	3.02	-93.22	-11.35	-6.05	-3.34	1.82	-	1.02														
							-6.48	-1.76	3.01	-93.22	-11.32	-6.09	-3.33	1.82	9.61	1.07														
			1200	9.7			-6.56	-1.89	2.51	-93.34	-11.47	-6.07	-3.41	1.67	9.64	.98														
							-6.57	-1.89	2.51	-93.35	-11.46	-6.07	-3.42	1.68	9.65	.98														
							-6.54	-1.88	2.51	-93.34	-11.45	-6.08	-3.43	1.68	9.65	.99														
							-6.55	-1.88	2.51	-93.33	-11.45	-6.08	-3.50	1.56	9.65	.99														
							-6.55	-1.89	2.51	-93.31	-11.45	-6.09	-3.45	1.66	9.65	.99														
							-6.54	-1.88	2.51	-93.30	-11.45	-6.09	-3.44	1.68	9.67	.99														
							-6.56	-1.93	2.51	-93.31	-11.45	-6.09	-3.44	1.69	9.64	.98														
							-6.55	-1.89	2.51	-93.33	-11.44	-6.08	-3.44	1.69	9.64	.99														
			1600	9.8			-6.54	-1.88	2.51	-93.30	-11.45	-6.10	-3.43	1.69	9.66	1.00														
							-6.54	-1.88	2.50	-93.30	-11.45	-6.09	-3.44	1.68	9.66	1.00														
							-6.54	-1.89	2.50	-93.27	-11.45	-6.09	-3.44	1.69	9.66	1.00														
							-6.54	-1.88	2.50	-93.29	-11.45	-6.09	-3.45	1.68	9.66	1.00														
							-6.54	-1.88	2.49	-93.28	-11.44	-6.09	-3.44	1.70	9.66	1.00														
							-6.54	-1.88	2.49	-93.30	-11.45	-6.09	-3.44	1.69	9.66	1.00														

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp., °F	Press., psig	N1		N2		N3		N4		N5		N6		N7		N8		N9		N10		N11		D24	
							-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2	-1	-2
Propellant cure cycle (cont'd)			2000	10.0			-6.51	-1.84	2.31	-91.67	-11.45	-6.02	-3.50	1.66	9.92	1.24														
							-6.51	-1.84	2.30	-91.67	-11.44	-6.03	-3.51	1.68	9.93	1.26														
							-6.50	-1.83	2.31	-91.66	-11.44	-6.04	-3.51	1.68	9.94	1.25														
							-6.50	-1.82	2.31	-91.66	-11.43	-6.04	-3.51	1.68	9.94	1.26														
							-6.49	-1.82	2.31	-91.66	-11.43	-6.04	-3.58	1.54	9.94	1.26														
			2400	10.0			-6.48	-1.80	2.24	-91.65	-11.39	-6.01	-3.52	1.69	10.03	1.35														
							-6.47	-1.79	2.25	-91.64	-11.36	-6.01	-3.52	1.68	10.04	1.35														
							-6.47	-1.79	2.25	-91.65	-11.38	-6.02	-3.52	1.69	10.05	1.36														
							-6.50	-1.80	2.24	-91.65	-11.34	-6.07	-3.53	1.69	10.04	1.35														
							-6.48	-1.77	2.25	-91.65	-11.36	-6.01	-3.54	1.69	10.05	1.37														
							-6.46	-1.78	2.25	-91.63	-11.37	-6.02	-3.62	1.53	10.05	1.36														
		11-13-72	0400	10.3			-6.44	-1.76	2.29	-91.78	-11.31	-5.99	-3.49	1.72	10.11	1.43														
							-6.44	-1.75	2.28	-91.78	-11.31	-6.00	-3.50	1.72	10.13	1.44														
							-6.43	-1.74	2.29	-91.77	-11.30	-6.00	-3.51	1.70	10.14	1.44														
							-6.42	-1.74	2.30	-91.77	-11.30	-6.01	-3.51	1.73	10.15	1.45														
							-6.42	-1.74	2.31	-91.77	-11.29	-6.01	-3.51	1.72	10.15	1.45														
							-6.42	-1.73	2.30	-91.77	-11.29	-6.01	-3.51	1.73	10.16	1.46														
		11-13-72	0900	10.6	116	15	-6.43	-1.75	2.29	-92.31	-11.28	-5.98	-3.62	1.51	10.18	1.46	7.53	10.18	17.97	19.15	20.92	34.01	11.47	2.82	10.30	5.72	20.76	-1.40	-1.78	1.27
							-6.42	-1.74	2.30	-92.31	-11.28	-5.98	-3.52	1.68	10.18	1.48	7.51	10.13	17.96	19.13	20.94	34.02	11.49	2.78	10.30	5.71	20.76	-1.37	-1.37	1.26
							-6.40	-1.73	2.34	-92.42	-11.25	-	-3.54	1.70	10.23	1.51														
	Alternate readings listed in this period.		1200	10.7			-6.35	-1.65	2.62	-93.27	-11.19	-5.98	-3.48	1.74	10.25	1.53														
							-6.35	-1.65	2.63	-	-11.18	-5.98	-3.48	1.77	10.25	1.53														
							-6.38	-1.72	2.64	-93.26	-11.17	-5.99	-3.47	1.79	10.26	1.54														
							-6.35	-1.64	2.65	-93.25	-11.17	-5.99	-3.47	1.79	10.24	1.53														
							-6.35	-1.64	2.66	-93.25	-11.16	-5.99	-3.47	1.80	10.26	1.54														
							-6.34	-1.63	2.66	-93.25	-11.16	-5.99	-3.47	1.81	10.26	1.55														
							-6.34	-1.63	2.67	-93.24	-11.16	-6.00	-3.48	1.80	10.27	1.54														
							-6.33	-1.62	2.68	-93.23	-11.16	-6.00	-3.47	1.82	10.27	1.55														
							-6.34	-1.63	2.68	-93.23	-11.15	-5.99	-3.47	1.82	10.27	1.55														
							-6.33	-1.61	2.68	-93.23	-11.15	-6.00	-3.48	1.82	10.27	1.55														
							-6.33	-1.51	2.70	-93.22	-11.15	-6.00	-3.48	1.82	10.27	1.55														
		11-13-72	1400	10.8	116	15	-6.35	-1.65	2.82	-93.14	-11.13	-5.98	-3.44	1.83	10.24	1.53	7.63	10.29	18.06	19.23	21.02	34.11	11.60	2.91	10.44	5.67	20.92	-1.21	-1.64	1.3
							-6.34	-1.63	2.82	-93.14	-11.12	-5.98	-3.44	1.83	10.24	1.53	7.65	10.31	18.07	19.24	21.03	34.11	11.61	2.91	10.44	5.67	20.93	-1.20	-1.62	1.30
	Alternate readings listed during this period.		1900	11.0			-6.34	-1.65	2.51	-93.23	-11.16	-5.94	-3.49	1.80	10.31	1.60														
							-6.33	-1.64	2.52	-93.22	-11.16	-5.95	-3.49	1.81	10.32	1.60														
							-6.33	-1.64	2.52	-93.21	-11.15	-5.95	-3.49	1.82	10.32	1.61														
							-6.33	-1.63	2.52	-93.21	-11.15	-5.96	-3.50	1.82	10.33	1.61														
							-6.32	-1.63	2.52	-93.22	-11.15	-5.96	-3.50	1.83	10.33	1.61														
							-6.32	-1.63	2.52	-93.22	-11.15	-5.96	-3.50	1.83	10.33	1.62														
							-6.34	-1.65	2.52	-93.19	-11.17	-6.00	-3.51	1.74	10.35	1.62														
							-6.33	-1.64	2.53	-93.17	-11.14	-5.94	-3.54	1.75	10.34	1.62														
			2400	11.2			-6.30	-1.64	2.53	-93.17	-11.15	-5.90	-3.60	1.81	10.31	1.59														
							-6.34	-1.62	2.53	-93.16	-11.15	-5.98	-3.54	1.75	10.36	1.64														
							-6.32	-1.66	2.56	-93.17	-11.11	-5.93	-3.55	1.77	10.36	1.64														
							-6.34	-1.66	2.56	-93.13	-11.13	-5.94	-3.51	1.72	10.43	1.72														
							-6.34	-1.58	2.57	-93.17	-11.13	-5.93	-3.50	1.81	10.34	1.63														
							-6.32	-1.63	2.54	-93.16	-11.09	-5.97	-3.63	1.62	10.36	1.66														
							-6.31	-1.61	2.60	-93.12	-11.09	-5.94	-3.58	1.74	10.39	1.72														
		11-14-72	0500	11.4			-6.49	-1.75	3.27	-92.51	-11.10	-5.79	-3.89	1.40	9.79	1.11														
							-6.51	-1.76	3.28	-92.51	-11.11	-5.78	-3.91	1.43	9.69	1.02														
							-6.57	-1.94	3.25	-92.52	-11.13	-5.78	-3.93	1.42	9.61	.95														
							-6.57	-1.83	3.23	-92.53	-11.14	-5.77	-3.96	1.40	9.51	.87														
							-6.58	-1.83	3.21	-92.54	-11.17	-5.77	-3.99	1.37	9.44	.80														
							-6.62	-1.89	3.23	-92.59	-11.17	-5.80	-3.99	1.34	9.40	.68														
							-6.64	-1.87	3.14	-92.55	-11.23	-5.78	-4.03	1.33	9.27	.67														
							-6.66	-1.91	3.14	-92.58	-11.22	-5.74	-4.10	1.25	9.22	.54														
	Cure pressure released Motor cooling already in progress.		1000	11.6	70	0	-9.52	-4.51	.09	-95.64	-13.44	-8.98	-6.70	-1.72	1.27	-6.77														
							-9.55	-4.52	.07	-95.65	-13.46	-9.02	-6.73	-1.79	1.28	-6.81														
							-9.54	-4.53	.10	-95.66	-13.43	-9.02	-6.71	-1.73	1.22	-6.80														
							-9.58	-4.64	.07	-95.67	-13.45	-9.05	-6.71	-1.72	1.20	-6.85														
							-9.57	-4.58	.09	-95.69	-13.44	-9.05	-6.74	-1.74	1.18	-6.87														
							-9.57	-4.57	.08	-95.69	-13.46	-9.07	-6.75	-1.76	1.15	-6.89														
							-9.58	-4.56	.05	-95.73	-13.47	-9.06	-6.78	-1.77	1.13	-6.92														
							-9.59	-4.55	.04	-95.76	-13.47	-9.08	-6.77	-1.76	1.10	-6.95														
			1500	11.8			-13.43	-8.36	-3.57	-101.44	-17.03	-11.49	-10.49	-5.54	-9.55	-17.21														
							-13.43	-8.34	-3.57	-101.45	-17.03	-11.50	-10.50	-5.53	-9.58	-17.20														
							-13.42	-8.34	-3.56	-101.40	-17.03	-11.50	-10.51	-5.53	-9.58	-17.21														
							-13.42	-8.34	-3.56	-101.40	-17.02	-11.50	-10.51	-5.53	-9.57	-17.20														
							-13.42	-8.34	-3.56	-101.40	-17.02	-11.50	-10.53	-5.54	-9.58	-17.21														
							-13.44	-8.32	-3.55	-101.40	-17.04	-11.51	-10.54	-5.55	-9.59	-17.22														

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, days	Temp. °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	C2N -1	C2N -2
			2000	12.0			-13.77	-8.64	-3.82	-100.43	-17.48	-10.41	-10.78	-5.86	-10.22	-17.77														
							-13.74	-8.63	-3.78	-100.40	-17.53	-10.35	-10.78	-5.79	-10.21	-17.80														
							-13.72	-8.64	-3.80	-100.42	-17.52	-10.37	-10.80	-5.77	-10.19	-17.80														
							-13.72	-8.63	-3.79	-100.43	-17.52	-10.37	-10.80	-5.78	-10.19	-17.80														
							-13.72	-8.63	-3.79	-100.43	-17.52	-10.37	-10.81	-5.77	-10.19	-17.80														
							-13.71	-8.64	-3.79	-100.42	-17.52	-10.37	-10.82	-5.79	-10.19	-17.80														
							-13.74	-8.65	-3.79	-100.44	-17.53	-10.36	-10.81	-5.78	-10.18	-17.80														
							-13.71	-8.63	-3.79	-100.46	-17.52	-10.36	-10.81	-5.77	-10.20	-17.80														
		11-15-72	0100	12.2			-13.92	-9.60	-3.97	-100.00	-17.82	-9.36	-10.99	-5.96	-10.59	-18.18														
							-13.92	-9.59	-3.96	-99.98	-17.82	-9.36	-10.99	-5.95	-10.59	-18.18														
							-13.93	-9.59	-3.98	-99.98	-17.80	-9.37	-11.00	-5.95	-10.58	-18.17														
							-13.91	-9.59	-3.97	-100.00	-17.81	-9.37	-11.00	-5.94	-10.58	-18.18														
							-13.92	-9.59	-3.96	-99.96	-17.81	-9.36	-11.01	-5.96	-10.58	-18.17														
			0600	12.4			-14.09	-10.77	-4.14	-99.56	-18.14	-8.49	-11.16	-6.13	-10.91	-18.52														
							-14.11	-10.83	-4.13	-99.54	-18.13	-8.50	-11.17	-6.11	-10.90	-18.52														
							-14.09	-10.78	-4.12	-99.51	-18.13	-8.49	-11.17	-6.11	-10.90	-18.53														
							-14.09	-10.77	-4.13	-99.52	-18.12	-8.50	-11.18	-6.10	-10.89	-18.52														
							-14.08	-10.76	-4.12	-99.51	-18.12	-8.49	-11.17	-6.09	-10.89	-18.51														
							-14.08	-10.75	-4.11	-99.50	-18.12	-8.49	-11.18	-6.10	-10.89	-18.52														
							-14.08	-10.75	-4.11	-99.51	-18.12	-8.49	-11.18	-6.10	-10.89	-18.51														
							-14.08	-10.76	-4.12	-99.48	-18.12	-8.49	-11.19	-6.11	-10.89	-18.51														
			1100	12.6			-13.51	-10.09	-3.68	-99.45	-17.55	-13.41	-10.54	-5.50	-10.14	-17.83														
							-13.51	-10.09	-3.68	-99.40	-17.55	-13.43	-10.56	-5.47	-10.14	-17.82														
							-13.50	-10.08	-3.67	-99.41	-17.54	-13.45	-10.53	-5.42	-10.13	-17.82														
							-13.51	-10.11	-3.65	-99.40	-17.53	-13.46	-10.49	-5.36	-10.13	-17.82														
							-13.50	-10.08	-3.65	-99.37	-17.53	-13.47	-10.53	-5.39	-10.12	-17.82														
							-13.48	-10.06	-3.65	-99.41	-17.53	-13.48	-10.52	-5.39	-10.12	-17.81														
							-13.49	-10.06	-3.64	-99.39	-17.54	-13.49	-10.53	-5.39	-10.12	-17.81														
							-13.48	-10.06	-3.64	-99.38	-17.53	-13.51	-10.54	-5.40	-10.12	-17.81														
		11-15-72	1445	12.8	70		-13.44	-9.60	-3.66	-99.67	-17.55	-14.00	-10.47	-5.36	-10.07	-17.78														
							-13.43	-9.57	-3.65	-99.67	-17.55	-14.01	-10.47	-5.34	-10.06	-17.77														
							-13.42	-9.55	-3.62	-99.66	-17.55	-14.01	-10.46	-5.36	-10.06	-17.77	-10.59	-7.46	-4.95	-1.94	- .01	2.70	-6.94	-15.99	-10.01	-14.02	-.22	-20.81	-7.99	-5.05
							-13.43	-9.58	-3.66	-99.68	-17.54	-14.02	-10.48	-5.35	-10.06	-17.77	-10.59	-7.46	-4.94	-1.93	- .01	2.70	-6.94	-15.99	-10.01	-14.02	-.22	-20.81	-7.99	-5.05
	Alternate readings listed during this period.		1900	13.0			-13.42	-9.48	-3.49	-99.02	-17.59	-14.76	-10.40	-5.18	-10.22	-17.91														
							-13.40	-9.45	-3.49	-99.02	-17.59	-14.77	-10.39	-5.11	-10.21	-17.91														
							-13.40	-9.46	-3.48	-99.02	-17.58	-14.77	-10.41	-5.17	-10.22	-17.90														
							-13.41	-9.48	-3.49	-99.03	-17.58	-14.77	-10.43	-5.18	-10.21	-17.89														
							-13.40	-9.48	-3.49	-99.03	-17.57	-14.78	-10.44	-5.19	-10.21	-17.89														
							-13.40	-9.47	-3.50	-99.02	-17.57	-14.78	-10.44	-5.19	-10.21	-17.89														
			2300	13.1			-13.51	-9.60	-3.67	-99.27	-17.74	-14.51	-10.51	-5.33	-10.39	-18.02														
							-13.49	-9.57	-3.66	-99.25	-17.72	-14.53	-10.53	-5.32	-10.38	-18.01														
							-13.49	-9.57	-3.65	-99.24	-17.72	-14.53	-10.53	-5.32	-10.37	-18.01														
							-13.49	-9.56	-3.64	-99.23	-17.72	-14.53	-10.54	-5.32	-10.37	-18.00														
							-13.49	-9.56	-3.64	-99.23	-17.71	-14.53	-10.54	-5.31	-10.37	-18.00														
							-13.49	-9.56	-3.64	-99.24	-17.71	-14.54	-10.54	-5.32	-10.37	-18.00														
							-13.48	-9.56	-3.64	-99.23	-17.71	-14.54	-10.54	-5.31	-10.36	-18.00														
							-13.48	-9.56	-3.64	-99.24	-17.71	-14.54	-10.55	-5.31	-10.36	-18.00														
		11-16-72	0300	13.3			-13.56	-9.57	-3.74	-98.57	-17.88	-14.29	-10.58	-5.40	-10.53	-18.12														
							-13.56	-9.57	-3.73	-98.57	-17.88	-14.30	-10.59	-5.39	-10.53	-18.11														
							-13.56	-9.56	-3.73	-98.56	-17.88	-14.30	-10.59	-5.39	-10.54	-18.05														
							-13.55	-9.55	-3.73	-98.56	-17.88	-14.30	-10.61	-5.42	-10.51	-18.10														
							-13.55	-9.55	-3.74	-98.57	-17.87	-14.31	-10.61	-5.40	-10.54	-18.11														
							-13.56	-9.57	-3.73	-98.57	-17.87	-14.30	-10.61	-5.38	-10.53	-18.11														
							-13.57	-9.56	-3.72	-98.57	-17.87	-14.30	-10.59	-5.38	-10.51	-18.09														
							-13.54	-9.53	-3.72	-98.57	-17.87	-14.32	-10.62	-5.38	-10.52	-18.11														
							-13.55	-9.54	-3.73	-98.57	-17.87	-14.31	-10.60	-5.38	-10.52	-18.10														
							-13.55	-9.53	-3.73	-98.57	-17.87	-14.31	-10.60	-5.38	-10.52	-18.11														
							-13.55	-9.53	-3.72	-98.57	-17.87	-14.31	-10.60	-5.38	-10.52	-18.11														
							-13.55	-9.54	-3.73	-98.57	-17.87	-14.30	-10.61	-5.38	-10.52	-18.11														
			0700	13.5			-13.64	-8.52	-3.92	-96.96	-18.04	-14.07	-10.66	-5.47	-10.69	-18.25														
							-13.63	-8.51	-3.92	-96.90	-18.04	-14.07	-10.66	-5.45	-10.68	-18.24														
							-13.64	-8.53	-3.91	-96.89	-18.03	-14.07	-10.66	-5.44	-10.68	-18.25														
							-13.63	-8.51	-3.91	-96.87	-18.03	-14.07	-10.67	-5.44	-10.68	-18.24														
							-13.62	-8.51	-3.91	-96.84	-18.03	-14.08	-10.67	-5.44	-10.68	-18.24														
							-13.62	-8.50	-3.91	-96.82	-18.03	-14.07	-10.67	-5.43	-10.68	-18.24														
							-13.62	-8.50	-3.91	-96.81	-18.03	-14.08	-10.67	-5.44	-10.67	-18.24														
							-13.62	-8.51	-3.91	-96.78	-18.03	-14.08	-10.68	-5.44	-10.67	-18.23														
			1100	13.7			-13.73	-8.61	-4.00	-95.97	-18.19	-13.85	-10.75	-5.55	-10.87	-18.42														
							-13.72	-8.60	-4.00	-95.97	-18.19	-13.85	-10.76	-5.56	-10.87	-18.41														
							-13.71	-8.60	-3.99	-95.97	-18.18	-13.86	-10.79	-5.59	-10.86	-18.40														
							-13.71	-8.59	-3.99	-95.97	-18.18	-13.86	-10.77	-5.55	-10.86	-18.40														
							-13.73	-8.63	-3.99	-95.96	-18.18	-13.86	-10.77	-5.54	-10.85	-18.40														
							-13.71	-8.59	-3.98	-95.97	-18.18	-13.86	-10.78	-5.54	-10.86	-18.40														
							-13.71	-8.57	-3.98	-95.97	-18.17	-13.86	-10.77	-5.54	-10.85	-18.40														
							-13.70	-8.56	-3.98	-95.99	-18.19	-13.86	-10.77	-5.53	-10.85	-18.39														
							-13.70	-8.58	-3.98	-95.99	-18.19	-13.86	-10.77	-5.53	-10.85	-18.39														
		11-16-72	1610	13.9	70		-13.76	-8.64	-4.08	-96.14	-18.30	-13.67	-10.77	-5.56	-10.96	-18.50	-11.32	-9.22	-6.04	-2.75	-1.13	.70	-7.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.23
							-12.76	-8.63	-4.08	-96.12	-18.30	-13.63	-10.77	-5.56	-10.96	-18.50	-11.32	-9.22	-6.04	-2.75	-1.13	.70	-7.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.23

TABLE H-1. FULL SCALE MOTOR NO.1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp. °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	[illegible] -1	[illegible] -2
	Alternate readings listed during this period.	11-16-72	2000	14.0	70		-13.80	-9.67	-4.19	-96.55	-18.41	-13.49	-6.02	-5.62	-11.06	-18.59														
							-13.79	-8.66	-4.19	-96.55	-18.41	-13.49	-6.02	-5.61	-11.06	-18.58														
							-13.79	-8.66	-4.18	-96.55	-18.41	-13.49	-6.01	-5.61	-11.05	-18.58														
							-13.79	-8.66	-4.18	-96.55	-18.40	-13.50	-6.01	-5.60	-11.05	-18.57														
							-13.78	-8.65	-4.18	-96.53	-18.40	-13.50	-6.01	-5.63	-11.05	-18.57														
							-13.79	-8.65	-4.18	-96.54	-18.40	-13.50	-6.00	-5.61	-11.05	-18.57														
							-13.80	-8.68	-4.18	-96.54	-18.40	-13.50	-6.00	-5.59	-11.04	-18.57														
							-13.78	-8.66	-4.17	-96.52	-18.40	-1350	-6.00	-5.60	-11.05	-18.57														
							-13.78	-8.65	-4.17	-96.51	-18.39	-13.50	-6.00	-5.60	-11.04	-18.57														
			2400	14.2			-13.81	-8.67	-4.15	-96.57	-18.48	-13.28	-6.06	-5.61	-10.92	-18.45														
							-13.80	-8.67	-4.14	-96.57	-18.48	-13.28	-6.05	-5.61	-10.92	-18.45														
							-13.80	-8.66	-4.14	-96.56	-18.47	-13.29	-6.05	-5.61	-10.92	-18.44														
							-13.80	-8.66	-4.13	-96.57	-18.47	-13.29	-6.04	-5.60	-10.91	-18.44														
							-13.79	-8.66	-4.14	-96.57	-18.47	-13.29	-6.04	-5.60	-10.91	-18.44														
							-13.79	-8.66	-4.13	-96.57	-18.47	-13.29	-6.04	-5.63	-10.91	-18.44														
							-13.79	-8.66	-4.14	-96.57	-18.47	-13.29	-6.04	-5.61	-10.90	-18.43														
							-13.81	-8.68	-4.13	-96.57	-18.47	-13.29	-6.04	-5.60	-10.91	-18.43														
		11-17-72	0400	14.3			-13.82	-8.69	-4.11	-96.58	-18.54	-	-6.13	-5.59	-10.86	-18.40														
							-13.82	-8.68	-4.10	-96.56	-18.53	-12.77	-6.12	-5.58	-10.88	-18.40														
							-13.81	-8.67	-4.09	-96.56	-18.53	-12.77	-6.12	-5.58	-10.87	-18.39														
							-13.80	-8.66	-4.09	-96.56	-18.52	-12.76	-6.12	-5.57	-10.86	-18.39														
							-13.79	-8.65	-4.09	-96.55	-18.52	-12.76	-6.12	-5.57	-10.86	-18.38														
							-13.79	-8.65	-4.09	-96.54	-18.52	-12.75	-6.11	-5.56	-10.86	-18.38														
							-13.79	-8.65	-4.08	-96.55	-18.52	-12.75	-6.11	-5.57	-10.86	-18.38														
							-13.79	-8.65	-4.08	-96.56	-18.51	-	-6.12	-5.56	-10.86	-18.38														
							-13.79	-8.65	-4.08	-96.54	-18.51	-	-6.11	-5.56	-10.86	-18.36														
							-13.79	-8.65	-4.08	-96.54	-18.52	-12.73	-6.11	-5.56	-10.85	-18.40														
							-13.79	-8.65	-4.08	-96.54	-18.51	-12.72	-6.11	-5.59	-10.85	-18.38														
			0800	14.5			-13.82	-8.67	-4.09	-96.59	-18.59	-12.23	-6.12	-5.54	-10.87	-18.40														
							-13.82	-8.67	-4.09	-96.59	-18.59	-12.24	-6.12	-5.54	-10.87	-18.39														
							-13.81	-8.66	-4.08	-96.60	-18.59	-12.24	-6.11	-5.53	-10.86	-18.39														
							-13.81	-8.66	-4.09	-96.60	-18.58	-12.24	-6.11	-5.53	-10.86	-18.38														
							-13.81	-8.66	-4.08	-96.59	-18.58	-12.24	-6.11	-5.53	-10.86	-18.39														
							-13.81	-8.66	-4.08	-96.59	-18.58	-12.24	-6.10	-5.53	-10.86	-18.38														
							-13.80	-8.66	-4.08	-96.60	-18.58	-12.25	-6.10	-5.52	-10.86	-18.38														
		11-17-72	0900	14.6	70		-13.81	-8.61	-4.08	-96.61	-18.51	-12.17	-6.13	-5.49	-10.88	-18.40	-11.30	-9.09	-6.29	-2.88	-1.34	.10	-7.52	-15.55	-11.04	-14.89	-1.34	-21.14	-8.89	-6.27
							-13.81	-8.63	-4.08	-96.62	-18.50	-12.17	-6.13	-5.50	-10.88	-18.40	-11.30	-9.09	-6.28	-2.88	-1.34	.09	-7.51	-16.55	-11.04	-14.89	-1.34	-21.15	-8.90	-6.27
							-13.81	-8.64	-4.08	-96.62	-18.50	-12.17	-6.13	-5.51	-10.88	-18.40	-11.30	-9.09	-6.28	-2.88	-1.34	.09	-7.51	-15.54	-11.04	-14.89	-1.33	-21.14	-8.89	-6.27
Core Pulling (The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)	No load on core	11-28-72	1740	25.9	70	0	-13.64	-8.54	-5.26	-96.28	-19.68	-11.52	-10.11	-4.67	-10.73	-18.20	-10.92	-8.47	-4.31	-2.36	-2.63	-1.75	-7.05	-16.09	-10.62	-14.36	-1.26	-21.39	-9.19	-6.30
							-13.65	-8.56	-5.26	-96.27	-19.68	-11.52	-10.12	-4.69	-10.73	-18.20	-10.93	-8.48	-4.31	-2.37	-2.64	-1.75	-7.05	-16.10	-10.63	-14.37	-1.26	-21.40	-9.11	-6.30
	10007 lb tension on cast dam						-13.64	-8.58	-5.41	-96.45	-19.78	-11.33	-10.10	-4.73	-10.76	-18.23	-10.97	-8.53	-4.41	-2.50	-2.72	-1.80	-7.07	-16.12	-10.68	-14.44	-1.32	-21.48	-9.23	-6.33
	"						-13.64	-8.57	-5.40	-96.45	-19.78	-11.34	-10.10	-4.72	-10.76	-18.23	-10.97	-8.53	-4.41	-2.50	-2.71	-1.82	-7.07	-16.12	-10.68	-14.44	-1.32	-21.48	-9.18	-6.33
	Zero load again						-13.72	-8.56	-5.27	-96.28	-19.63	-11.49	-10.12	-4.73	-10.75	-18.22	-10.89	-8.44	-4.38	-2.43	-2.69	-1.76	-7.09	-16.14	-10.69	-14.43	-1.31	-21.47	-9.04	-6.32
	"						-13.73	-8.58	-5.26	-96.29	-19.63	-11.49	-10.14	-4.74	-10.75	-18.22	-10.89	-8.44	-4.36	-2.40	-2.70	-1.80	-7.08	-16.13	-10.68	-14.43	-1.29	-21.45	-8.79	-6.32
	500 lb tension						-13.74	-8.65	-5.33	-96.36	-19.71	-11.38	-10.18	-4.83	-10.76	-18.24	-10.97	-8.54	-4.41	-2.49	-2.76	-1.86	-7.11	-16.16	-10.73	-14.50	-1.33	-21.50	-8.85	-6.32
	1000 lb						-13.69	-8.60	-5.40	-96.45	-19.71	-11.31	-10.15	-4.80	-10.76	-18.23	-10.97	-8.55	-4.44	-2.54	-2.79	-1.88	-7.11	-16.16	-10.75	-14.52	-1.35	-21.53	-8.85	-6.33
	1500 lb						-13.66	-8.57	-5.39	-96.56	-19.69	-11.21	-10.14	-4.78	-10.76	-18.24	-10.99	-8.56	-4.51	-2.62	-2.83	-1.92	-7.13	-16.18	-10.79	-14.5[illegible]	-1.38	-21.58	-8.81	-6.34
	2000 lb						-13.65	-8.55	-5.29	-97.14	-19.67	-11.16	-10.13	-4.77	-10.77	-18.24	-10.99	-8.57	-4.57	-2.71	-2.84	-1.94	-7.13	-16.19	-10.81	-14.59	-1.42	-21.63	-8.87	-6.35
	2500 lb						-13.61	-8.53	-5.25	-97.18	-19.59	-11.06	-10.11	-4.76	-10.78	-18.25	-11.02	-8.60	-4.60	-2.75	-2.84	-1.95	-7.14	-16.19	-10.82	-14.60	-1.45	-21.68	-8.86	-6.36
	3000 lb cast dam released						-13.79	-8.66	-4.81	-96.38	-19.72	-11.77	-10.16	-4.77	-10.76	-18.24	-11.01	-8.60	-4.39	-2.46	-2.72	-1.80	-7.12	-16.17	-10.71	-14.48	-1.34	-21.54	-6.72	-6.26
	Zero load						-13.76	-8.59	-5.17	-96.72	-19.71	-11.62	-10.15	-4.78	-10.67	-18.15	-10.88	-8.46	-4.29	-2.30	-2.66	-1.75	-7.04	-16.09	-10.63	-14.40	-1.23	-21.38	-8.75	-6.21
	500 lb						-13.71	-8.58	-5.12	-96.70	-19.66	-11.43	-10.17	-4.82	-10.54	-18.03	-10.77	-8.34	-4.19	-2.17	-2.56	-1.66	-6.89	-15.93	-10.52	-14.29	[illegible]	-21.25	-8.51	-6.08
	1000 lb						-13.69	-8.57	-5.08	-96.70	-19.62	-11.30	-10.14	-4.79	-10.39	-17.90	-10.67	-8.25	-4.12	-2.08	-2.47	-1.58	-6.71	-15.74	-10.43	-14.20	-1.37	-21.17	-8.20	-5.78
	Mandrel free						-13.82	-8.66	-5.05	-96.98	-19.56	-11.41	-10.32	-5.02	-10.57	-18.06	-10.96	-8.57	-5.85	-2.32	-2.67	-1.73	-6.98	-16.04	-10.65	-14.46	-1.67	-21.39	-8.39	-5.99
	"						-13.81	-8.65	-5.12	-97.01	-19.56	-11.42	-10.32	-5.02	-10.57	-18.06	-10.92	-8.53	-5.84	-2.31	-2.68	-1.75	-6.98	-16.04	-10.62	-14.43	-1.68	-21.37	-8.42	-5.99
	Mandrel removed	11-29-72	1000	26.6			-13.08	-7.91	-3.11	-98.54	-16.99	-9.38	-9.65	-4.39	-11.40	-18.83	-11.22	-8.80	-5.15	-1.95	-1.90	-1.27	-5.15	-14.09	-8.65	-12.35	-1.38	-18.23	-10.83	-7.88
	"						-13.08	-7.91	-3.11	-98.55	-16.99	-9.38	-9.64	-4.37	-11.40	-18.83	-11.22	-8.80	-5.16	-1.95	-1.90	-1.28	-5.15	-14.09	-8.65	-12.35	-1.38	-18.23	-10.88	-7.88
Motor Pressurization (The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)	Motor in horizontal attitude.	12-19-72		46.5	87	0	1500.	-1508.	1499.	-1506.	-17.	-10.	-11.	-3.	-8.	-15.	-8.	-6.	1.	3.	0.	5.	1548.	-1543.	1544.	-1541.	1540.	-1544.	-10.	-6.
							-1500.	1499.	1504.	-1520	-16.	-10.	-10.	-3.	-8.	-16.	-8.	-5.	1.	3.	-1.	4.	1535.	-1546.	1558.	-1547.	1541.	-1544.	-12.	-5.
						9.375	-1554.	1565.	1571.	-1567.	-16.	-8.	-8.	1.	0.	-8.	-0.	2.	9.	11.	7.	11.	1612.	1612.	1584.	1612.	1597.	1618.	-1610.	-2.
							-1560.	1556.	1563.	-1567.	-16.	-8.	-7.	1.	1.	-8.	-0.	3.	9.	11.	7.	11.	1633.	1613.	-1601.	-1615.	-1612.	1612.	1590.	-3.
						19.93	-1574.	1571.	1572.	-1582.	-14.	-7.	-5.	1.	8.	1.	8.	10.	17.	19.	15.	19.	1602.	1590.	-1613.	-1601.	-1603.	1594.	-4.	-0.
							-1574.	-1581.	1584.	1583.	-13.	-7.	-5.	1.	8.	0.	8.	10.	17.	19.	15.	19.	1603.	1593.	-1592.	-1603.	1606.	1607.	-5.	-0.
						29.72	-1576.	-1577.	1580.	1579.	-11.	-4.	-1.	3.	15.	6.	16.	18.	24.	27.	23.	26.	-1602.	-1607.	-1606.	1604.	1607.	-1600.	-1607.	3.
							-1573.	1573.	1573.	1587.	-11.	-5.	-1.	5.	14.	6.	16.	18.	24.	26.	23.	27.	-1608.	1613.	1607.	-1608.	-1605.	-1609.	1607	2.
						40.178	1581.	1583.	-1575.	-1587.	-9.	-2.	1.	7.	23.	14.	23.	25.	32.	34.	30.	34.	1596.	1599.	1608.	1604.	1600.	-1598.	2.	7.
							1563.	-1563.	-1570.	-1587.	-9.	-3.	1.	7.	23.	14.	23.	26.	32.	34.	31.	34.	1605.	1600	-1608.	-1616.	1610.	1606.	-0.	5.
						50.51	-1590.	1580.	1581.	-1586.	-7.	-1.	4.	10.	31.	21.	30.	33.	40.	42.	38.	42.	1614.	1606	-1616.	-1614.	-1610.	1613.	4.	8.
							1582.	1577.	-1572.	-1589.	-6.	-0.	4.	10.	30.	21.	31.	33.	40.	42.	38.	43.	1610.	1604.	1611.	1598.	-1614.	1608.	4.	8.
		12-28-72	1000	55.6		0	-12.	-2.	-4.	-108.	-16.	-12.	-6.	0.	-7.	-13.	-6.	-1.	-0.	2.	0.	0.	-6.	-15.	-6.	-10.	-1.	-21.	-11.	-5.
						9.44	-8.	-0.	-1.	-114.	-13.	-9.	-3.	0.	0.	-6.	-0.	3.	5.	10.	5.	9.	-0.	-8.	-0.	-3.	5.	13.	-6.	-2.
							-8.	-0.	-0.	-114.	-13.	-10.	-4.	1.	0.	-6.	-0.	3.	5.	10.	6.	8.	-0.	-9.	-0.	-3.	5.	-12.	-8.	-2.
						19.31	-6.	-0.	-0.	-95.	-11	-7.	-1.	4.	7.	0.	6.	12.	17.	18.	15.	16.	6.	1.	5.	3.	13.	-4.	-6.	-0.
							-6.	-0.	-0.	-94.	-11.	-8.	0.	3.	6.	0.	7.	12.	14.	19.	15.	16.	5.	-1.	5.	3.	13.	-3.	-5.	-0.
						29.72	-3.	3.	-0.	-93.	-10.	-6.	0.	5.	15.	6.	15.	19.	24.	27.	22.	25.	14.	4.	15.	12.	22.	0.	1.	1.
							-4.	3.	-0.	-93.	-9.	-6.	1.	5.	15.	6.	15.	20.	24.	28.	23.	24.	14	4.	16.	11.	23.	0.	[illegible]	0.
						39.59	-1.	6.	1.	-95.	-7.	-4.	2.	7.	22.	14.	23.	27.	31.	36.	31.	32.	22.	13.	23.	18.	31.	11.	[illegible]	6.
							-1.	6.	1.	-95.	-8.	-4.	2.	8.	22.	14.	23.	27.	32.	35.	31.	32.	22.	13.	23.	18.	30.	3.	[illegible]	5.
						49.45	-0.	9.	3.	-77.	-4.	-2.	5.	11.	29.	21.	31.	34.	40.	41.	39.	40.	30.	21.	31.	27.	31.	-8.	2.	5.
							-0.	10.	5.	-77.	-4.	-2.	4.	10.	29.	20.	31.	34.	39.	43.	39.	39.	32.	22.	30.	27.	39.	19.	1.	7.
		1-4-73	0830	62.5	90	0	-12.38	-5.30	-3.85	-99.79	-18.24	-8.51	- .00	-3.90	-9.84	-16.99	-	-												
						9.36	-9.72	-2.71	-1.80	-101.39	-16.12	-6.68	-6.93	-1.25	-2.55	-10.24	- .24	1.04												
						19.84	-6.75	.13	.52	-103.65	-14.96	-4.91	-3.98	1.67	5.72	-2.58	8.00	9.26												
						30.11	-3.86	2.99	2.66	-112.09	-12.66	-3.32	-1.15	4.51	13.82	4.92	16.01	17.32												
						41.03	- .86	5.91	5.06	-107.86	-10.52	-1.63	1.82	7.34	22.35	12.81	24.44	25.76												
						50.34	1.75	6.44	6.96	-90.39	-8.24	.16	4.35	9.38	29.75	19.72	31.68	32.90												
						0											-7.53	-6.02												

TABLE H-1. FULL SCALE MOTOR NO. 1 NORMAL GAGE OUTPUT LOG, MILLIVOLTS (CONT.)

Test	Motor Conditions	Date	Time	Elapsed Time, Days	Temp. °F	Press., psig	N1 -1	N1 -2	N2 -1	N2 -2	N3 -1	N3 -2	N4 -1	N4 -2	N5 -1	N5 -2	N6 -1	N6 -2	N7 -1	N7 -2	N8 -1	N8 -2	N9 -1	N9 -2	N10 -1	N10 -2	N11 -1	N11 -2	D2N -1	D2N -2
110°F Aging	Motor placed in 110°F environment 1-8-73	1-8-73		66.5	64*	0	-11.91	-4.67	-4.19	-136.02	-19.16	-4.64	-8.68	-2.80	-10.77	-18.00	-7.52	-5.92	-2.52	1.32	-1.74	-1.40	-8.15	-17.11	-10.55	-14.00	-2.45	-22.33	-11.80	-5.83
		1-8-73	1530	66.8	101		-12.39	-5.69	-4.24	-136.38	-18.55	-2.92	-8.96	-3.61	-10.39	-17.62	-8.04	-6.77	-1.18	2.35	-1.26	3.19	-8.54	-17.44	-10.35	-14.23	-1.73	-21.73	-12.92	-6.96
	*Indicated temperature taken at T_2 during 110°F aging	1-9-73	0830	67.5	109		-12.69	-5.72	-3.43	-127.53	-17.57	-1.61	-9.08	-3.59	-9.94	-17.46	-7.87	-6.54	-	3.64	- .70	7.52	-8.62	-17.52	-9.56	-13.79	- .01	-20.97	-12.24	-7.26
		1-9-73	1545	67.8	108		-12.68	-5.70	-3.24	-125.00	-17.34	-1.36	-9.02	-3.52	-9.80	-17.37	-7.75	-6.40	-3.97	2.23	- .54	8.03	-8.50	-17.40	-9.33	-13.57	.23	-20.85	-14.20	-7.20
		1-10-73	0950	68.5	108		-12.60	-5.61	-2.68	-121.21	-16.49	-1.00	-8.84	-3.45	-9.36	-17.02	-7.40	-6.12	-3.31	2.94	- .15	9.05	-8.12	-17.02	-8.91	-13.23	.81	-20.50	-13.35	-7.04
		1-10-73	1530	68.8	108		-12.59	-5.59	-2.52	-118.20	-16.45	- .87	-8.82	-3.43	-9.31	-17.00	-7.36	-6.06	-3.23	3.06	- .09	9.32	-8.10	-16.98	-8.83	-13.15	.82	-20.48	-13.85	-7.07
		1-11-73	1530	69.8	109		-12.49	-5.49	-2.66	-120.95	-16.21	- .63	-8.65	-3.28	-9.03	-16.86	-7.07	-5.72	-2.85	3.53	16.95	10.03	-7.85	-16.73	-8.50	-12.84	1.09	-20.31	-13.49	-7.05
		1-12-73	0920	70.5	109		-12.44	-5.43	-1.90	-122.07	-15.91	- .37	-8.52	-3.19	-8.88	-16.80	-6.87	-5.55	-2.64	3.78	- .35	10.40	-7.68	-16.54	-8.30	-12.67	1.25	-20.18	-14.27	-7.01
		1-12-73	1430	70.8	110		-12.45	-5.43	-2.11	-122.32	-15.89	- .38	-8.52	-3.18	-8.88	-16.82	-6.86	-5.53	-2.63	3.79	- .35	10.46	-7.66	-16.52	-8.29	-12.65	1.26	-20.18	-15.57	-7.01
		1-15-73	1505	73.8	109		-12.46	-5.50	-1.27	-122.20	-15.52	- .07	-8.53	-3.40	-8.98	-17.13	-6.87	-5.83	-2.55	3.96	- .23	10.81	-7.62	-16.46	-8.32	-12.73	1.36	-20.21	-15.75	-7.19
		1-22-73	1500	80.8	107		-12.33	-5.46	-1.07	-120.14	-15.24	- .11	-8.32	-3.29	-8.85	-17.26	-6.31	-5.60	-2.20	4.57	.63	11.04	-7.23	-15.05	-8.15	-12.53	1.97	-19.61	-19.11	-7.46
		1-31-73	0930	89.6			-12.27	-5.72	- .79	-119.56	-15.08	.04	-8.20	-3.08	-8.54	-17.17	-5.81	-4.53	-1.70	5.22	1.08	11.98	-6.70	-15.49	-7.94	-12.29	2.67	-18.91	-11.45	-7.75
		2-8-73	1100	97.6			-12.55	-6.43	- .64	-119.32	-15.07	.00	-8.33	-2.98	-8.43	-17.19	-5.50	-3.02	-1.44	5.53	.86	11.56	-6.41	-15.21	-7.86	-12.15	2.73	-18.81	-14.31	-7.88
		2-16-73		105			-12.87	-6.81	- .59	-119.32	-15.12	- .15	-8.56	-3.18	-8.62	-17.48	-5.33	-4.13	-1.30	5.76	.54	11.03	-6.39	-15.18	-8.01	-12.24	2.48	-19.07	-15.69	-8.27
		2-21-73		110			-12.82	-6.89	- .60	-119.47	-15.18	- .29	-8.60	-3.30	-8.74	-17.65	-5.30	-4.13	-1.29	5.81	.77	11.17	-6.28	-15.04	-8.12	-12.31	2.58	-18.99	-14.72	-8.30
		3-2-73		120			-13.20	-7.02	- .35	-119.30	-15.09	- .27	-8.76	-3.34	-8.46	-17.50	-4.85	-4.13	- .80	6.32	.65	11.15	-5.90	-14.69	-7.97	-12.15	2.69	-18.66	-14.23	-8.24
		3-2-73					-13.20	-7.02	- .36	-119.31	-15.10	- .28	-8.77	-3.34	-8.47	-17.50	-4.85	-4.13	- .80	6.31	.64	11.14	-5.91	-14.68	-7.97	-12.15	2.89	-18.67	-14.30	-8.24
(The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)		3-9-73		127			-13.39	-7.17	- .24	-118.61	-15.23	- .43	-8.82	-3.35	-8.71	-17.63	-4.77	-3.17	- .65	6.56	.73	11.41	-5.89	-14.65	-8.07	-12.21	2.82	-18.71	-13.01	-8.50
		3-13-73		131			-13.36	-7.14	- .18	-118.21	-15.16	- .59	-8.82	-3.39	-8.52	-17.68	-4.61	-4.06	- .54	6.68	.87	11.27	-5.72	-14.46	-8.10	-12.21	3.04	-18.57	-12.45	-8.25
		3-29-73		147			-12.96	-6.94	- .20	-111.17	-15.26	- .69	-8.80	-3.36	-8.25	-17.56	-4.18	-2.44	.11	7.35	1.03	11.70	-4.97	-13.20	-7.58	-11.34	3.17	-17.12	-14.04	-8.23
		4-16-73	1600	165			-13.43	-7.24	.09	-112.60	-15.41	- .92	-8.77	-3.31	-8.12	-17.59	-3.80	-2.17	.65	7.91	1.10	11.89	-4.64	-12.85	-7.67	-11.37	3.32	-16.95	-14.36	-8.02
		4-24-73		173			-13.49	-7.29	.15	-113.88	-15.51	-1.06	-8.75	-3.32	-	-17.75	-3.77	-2.20	.73	8.04	1.26	10.13	-4.70	-12.88	-7.85	-11.53	3.30	-16.97	-15.61	-8.07
		5-14-73		193	110		-15.01	-8.38	.10	-123.84	-17.06	-2.15	-9.47	-4.12	-8.34	-17.96	-3.80	-3.78	1.19	8.42	.73	12.30	-4.89	-13.61	-8.58	-12.43	3.42	-18.19	-11.82	-8.67
		5-15-73		194	110		-14.19	-	- .72	-116.77	-17.40	-2.66	-9.45	-4.16	-8.59	-18.17	-3.88	-3.79	-.00	- .19	.36	10.65	-4.80	-13.05	-8.44	-11.94	2.81	-17.38	-10.71	-8.38
		5-18-73		197			-15.92	-9.13	-4.60	-130.15	.14	.13	.09	.08	.10	.10	.06	.07	.07	.12	.07	.11	-6.39	-15.27	-10.80	-14.59	.31	-20.95	.12	.10
Thermal Cycling	Motor placed in 80°F environment on 7-19-73. Horizontal attitude.	7-19-73		259	80		- .14	- .06	.01	- .13	.00	.00	.00	.00	.56	.01	.00	.00	.01	.00	.02	-	.05	.11	.08	.14	.02	.16	.00	.01
		7-20-73		260			.08	.05	.00	- .07	.00	.01	.00	.00	.00	.00	.01	.00	.00	.01	.00	-	.04	.10	.08	.11	.02	.17	.00	.01
		7-23-73		263			.08	.05	.00	- .07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	-	.03	.07	.05	.06	.00	.12	.00	.01
		7-24-73		264			-18.19	-10.98	-4.81	-100.38	.01	.00	.02	.00	.00	.02	.01	.00	.01	.01	.01	-	-4.46	-12.69	-10.61	-12.69	-1.15	-20.30	.00	.00
		7-25-73		265			-18.29	-11.08	-4.88	-100.40	.01	.02	.01	.00	.00	.02	.01	.01	.01	.01	.01	-	-4.66	-12.81	-11.05	-12.90	- .59	-20.79	.01	.00
		7-27-73		267			-18.41	-11.21	-4.94	-100.27	.05	.05	.03	.03	.56	.04	.03	- .00	.00	.00	.00	.00	-4.85	-12.90	-11.49	-13.04	- .32	-21.14	.01	.00
		7-30-73		270			-18.34	-11.16	-4.85	-100.31	.02	.02	.02	.02	.01	.02	- .01	- .00	.01	.00	.00	.01	-5.19	-13.17	-11.83	-13.18	- .46	-21.01	.01	.00
		7-30-73					-18.61	-11.38	-4.88	-100.21	-23.77	-10.14	-11.83	-7.39	.24	.22	.18	.23	.33	.21	-7.66	-7.00	-6.03	-13.22	-11.50	-14.04	- .46	-21.03	-14.28	-9.54
	Motor conditioning temperature changed to 60°F on 7-31-73	7-31-73		271			-18.60	-11.33	-4.25	-100.42	-24.10	-10.52	-12.03	-7.49	.05	.05	.05	.06	.07	.05	-8.03	-8.73	-4.95	-12.40	-11.18	-13.24	- .46	-20.95	-44.58	-11.11
		8-1-73		272	60		-19.03	-11.73	-4.30	-100.42	-24.85	-11.21	-12.42	-7.88	.04	.04	.04	.05	.06	.04	-9.03	-10.27	-5.25	-12.52	-12.52	-14.45	-2.24	-22.35	-52.40	-12.97
		8-3-73		274			-19.18	-11.87	-4.33	-100.03	-24.84	-11.37	-12.54	-8.00	.04	.04	.04	.05	.06	.04	-9.44	-10.75	-5.41	-12.64	-13.02	-14.86	-2.78	-22.79	-59.71	-13.36
		8-6-73		277			-19.41	-12.06	-4.15	-100.43	-24.66	-11.47	-12.67	-8.11	.03	.04	.03	.05	.04	.04	-10.05	-11.56	-5.71	-12.84	-13.77	-15.46	-3.33	-23.26	-56.47	-13.31
		8-7-73		278			-	-12.06	-4.11	-100.95	-24.66	-11.46	-12.61	-8.07	- .02	.03	- .02	- .02	- .03	- .02	-10.09	-11.58	-5.75	-12.06	-13.89	-15.52	-3.38	-23.31	-65.68	-13.39
	Motor conditioning temperature changed to 110°F on 8-9-73	8-9-73		280			-19.62	-12.21	-4.10	-100.95	-24.72	-11.53	-12.66	-8.14	.02	.03	.01	.01	.02	.01	-10.96	-12.01	-5.90	-12.99	-14.12	-15.64	-3.56	-23.45	-62.04	-14.11
		8-10-73		281	110		-19.30	-11.98	-4.01	-100.46	-24.54	-10.41	-12.43	-7.75	.02	.01	.02	.02	.02	.02	-9.23	-7.35	-5.68	-12.87	-12.79	-14.51	- .89	-21.40	-59.06	-14.13
		8-13-73		284			-19.09	-11.73	-4.44	-100.46	-23.74	-9.47	-12.28	-7.72	.01	.03	.03	.02	.04	.03	-7.87	-2.05	-6.33	-13.00	-12.09	-13.72	.82	-20.62	-44.60	-13.29
		8-14-73		285			-18.90	-11.67	-4.37	-100.48	-22.84	-9.14	-12.48	-7.73	.02	.06	.00	.03	.05	.03	-6.56	-3.15	-6.57	-13.60	-11.78	-13.42	2.09	-20.07	-43.71	-13.44
		8-20-73		291			-18.16	-11.23	-3.37	-100.44	-22.36	-8.48	-12.11	-7.49	.03	.03	.01	.02	.03	.03	-3.39	-7.74	-6.30	-12.94	-12.28	-13.23	4.56	-18.28	-37.01	-12.36
		8-21-73		292			-17.62	-10.84	-3.25	-100.43	-21.90	-7.34	-11.86	-7.34	.03	.03	.02	.03	.03	.03	-3.08	-7.87	-6.11	-12.53	-12.17	-13.02	4.62	-17.64	-35.96	-11.98
		8-23-73		294			-17.37	-10.83	-2.23	-100.09	-21.11	-7.75	-11.49	-6.99	-16.70	-28.27	-10.04	-11.75	-3.34	3.04	-2.33	-8.95	-6.14	-12.50	-12.33	-13.09	5.23	-17.12	-36.65	-10.98
(The signs of the recorded values for N3-2, N4-1, and N8-2 have been reversed to show a positive response to an increasing compressive stress)	Motor conditioning temperature changed to 80°F on 8-24-73	8-24-73		295			-17.34	-10.55	-2.16	-100.08	-21.13	-7.77	-11.43	-6.92	-18.59	-28.21	-10.01	-11.70	-3.24	3.11	-2.14	-9.23	-6.18	-12.49	-12.48	-13.15	5.43	-16.91	-36.19	-10.79
		8-27-73		298	80		-17.93	-11.00	-3.53	-100.03	-22.06	-9.50	-11.53	-7.02	-17.88	-29.09	-10.24	-11.89	-6.39	.39	-4.15	.83	-7.00	-13.37	-14.15	-16.39	3.10	-18.07	-23.68	-10.72
		8-28-73		299			-18.09	-11.16	-3.64	-100.06	-22.27	-9.62	-11.63	-7.09	-17.91	-29.16	-10.40	-12.16	-6.67	.15	-4.45	.52	-7.14	-13.49	-14.42	-14.63	2.88	-18.16	-44.63	-10.86
		8-29-73		300			-18.18	-11.21	-3.69	-100.04	-22.39	-9.72	-11.71	-7.14	-18.05	-29.20	-10.53	-12.28	-6.87	- .03	-4.73	.13	-7.28	-13.63	-14.68	-14.86	2.66	-18.30	-46.93	-10.93
		8-31-73		302			-18.33	-11.30	-3.71	-100.05	-22.49	-9.80	-11.70	-7.14	-18.07	-29.22	-10.63	-12.37	-7.02	- .17	- .20	.34	-7.37	-13.69	-14.92	-15.05	2.44	-18.47	-47.29	-11.05
		9-4-73		306			-18.44	-11.35	-3.74	-	-22.50	-9.81	-11.70	-7.05	-18.05	-29.18	-10.64	-12.40	-6.93	- .05	-5.57	.67	-7.53	-13.80	-15.15	-15.21	2.17	-18.77	-48.07	-11.18
	Motor conditioning temperature changed 60°F on 9-5-73	9-5-73		307			-18.35	-11.22	-3.67	-100.27	-22.45	-9.69	-11.58	-6.97	-17.92	-29.07	-10.54	-12.30	-6.78	.25	-5.42	.35	-7.57	-13.84	-15.10	-15.16	2.35	-18.66	-46.21	-10.94
		9-6-73		308	60		-18.63	-11.33	-3.62	-100.40	-23.40	-11.13	-11.61	-7.12	-18.25	-29.63	-10.41	-12.09	-8.37	-1.38	-6.34	-5.70	-7.32	-13.51	-15.90	-15.59	.53	-19.60	-45.32	-10.79
		9-7-73		309			-18.89	-11.61	-3.76	-100.84	-23.76	-11.59	-11.83	-7.33	-18.40	-29.79	-10.85	-12.47	-9.37	-2.27	-6.90	-6.55	-7.41	-13.55	-16.48	-18.11	- .54	-20.42	-49.26	-11.28
		9-10-73		312			-19.38	-12.01	-3.96	-100.32	-24.41	-12.01	-12.08	-7.56	-18.61	-30.06	-11.67	-13.22	-10.44	-3.41	-8.06	-8.09	-7.61	-13.67	-17.66	-17.21	-2.13	-21.79	-52.74	-12.19
		9-11-73		313			-19.48	-12.14	-3.95	-100.46	-24.57	-12.00	-12.15	-7.59	-18.62	-30.08	-11.75	-13.32	-10.83	-3.54	-8.36	-8.37	-7.74	-13.74	-17.86	-17.46	-2.31	-22.06	-58.22	-
		9-12-73		314			-19.69	-12.15	-4.12	-100.35	-24.67	-11.98	-12.25	-7.55	-18.82	-30.27	-12.02	-13.54	-10.92	-3.79	-8.50	-8.46	-7.84	-13.86	-18.04	-17.55	-2.56	-22.16	-59.14	-12.51
		9-13-73		315			-19.79	-12.20	-4.12	-100.31	-24.64	-12.11	-12.18	-7.56	-18.83	-30.24	-11.90	-13.57		-3.83	-9.76	-8.85	-7.92	-13.89	-18.05	-17.64	-2.74	-22.21	-62.79	-12.49
		9-14-73		316			-19.98	-12.49	-4.16	-100.78	-24.77	-12.16	-12.32	-7.68	-18.99	-30.34	-12.07	-13.29	-10.97	-3.82	-9.05	-9.18	-8.02	-14.05	-18.32	-17.79	-2.93	-22.47	-63.07	-12.58
	Motor conditioning temperature changed to 110°F on 9-17-74	9-17-73		319			-19.93	-12.38	-4.13	-100.94	-24.61	-11.98	-12.20	-7.45	-18.64	-30.21	-11.86	-12.83	-10.73	-3.63	-9.17	-9.23	-7.96	-13.91	-18.12	-17.68	-2.94	-22.39	-65.53	-12.66
		9-20-73		322	110		-19.37	-11.82	-3.65	-100.84	-22.64	-9.01	-9.58	-6.63	-17.67	-29.69	-10.89	-12.01	-5.79	1.07	-6.61	-2.53	-8.64	-14.82	-15.77	-15.85	-1.22	-20.21	-63.09	-12.08
Vibration Test (BC readings)		12-19-73	1155	412	76		-	-12.6	-4.8	-	-24.9	-12.1	-11.6	-8.6	-18.5	-	-10.6	-	-7.9	-	-8.3	-	-13.4	-	-22.6	-	-6.29	-		-9.7
		1-10-74		434	75		-	-13.4	-4.61	-	-27.2	-	-	-9.4	-19.11	-	-10.4	-	-7.79	-	-8.05	-	-13.79	-	-22.8	-	-6.23	-	-	-10.29

TABLE H-2

POST CURE-PRESSURE CALIBRATION TEST FOR MOTOR #1

TEMP: 80 ± 5°F
(Output in mv)

PSIG PRESSURE	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
0	-2.248	+5.225	+.814	+6.521	-14.316	+4.637	+7.353	+.011	-9.413	-2.887
9.356	-.980	+4.887	-2.093	+6.597	-11.11	+3.437	+5.455	-.839	-5.033	-.768
19.84	-.057	+4.689	-4.492	+6.655	-7.410	+2.322	+3.732	-1.433	+.827	+1.572
30.11	+.627	+4.595	-6.410	+6.667	-3.974	+1.571	+2.463	-1.893	+7.167	+3.865
41.03	+1.221	+4.529	-8.158	+6.712	-.581	+.96	+.723	-2.184	+14.27	+6.067
50.34	+1.693	+4.485	-9.787	+7.063	+2.138	+.380	-.799	-1.971	+20.82	+7.930

PSIG PRESSURE	S-11	S-12	S-13	S-14	N-1-1	N-1-2	N-2-1	N-2-2	N-3-1	N-3-1
0	+2.736	+2.933	+2.217	-1.839	-12.38	-5.2	-3.848	-99.79	-18.24	+8.514
9.356	+1.856	-.789	-6.839	-1.747	-9.718	-2.709	-1.800	-1.391	-1.611	+6.67
19.84	+.648	-4.42	-14.36	-1.666	-6.749	+.177	+.522	-3.647	-14.96	+4.909
30.11	-.591	-7.560	-21.16	-1.529	-3.861	+2.987	+2.658	-12.08	-12.66	+3.317
41.03	-2.006	-10.59	-28.67	-1.249	-.855	+5.905	+5.05	-7.86	-10.62	+1.633
50.34	-3.59	-13.12	-36.56	-.814	+1.749	+8.437	+6.962	-90.39	-8.24	-.160

TABLE H-2 (CONTINUED)

POST CURE-PRESSURE CALIBRATION TEST FOR MOTOR #1

(Output in mv)

PSIG PRESSURE	N-4-1	N-4-2	N-5-1	N-5-2	N-6-1	N-6-2
0	+.000	-3.903	-9.84	-16.99	-7.53	-6.015
9.456	+6.928	-1.250	-2.545	-10.23	-.241	+1.041
19.84	+3.978	+1.674	+5.721	-2.582	+7.998	+9.263
30.11	+1.145	+4.509	+13.82	+4.922	+16.014	+17.322
41.03	-1.816	+7.444	+22.34	+12.81	+24.44	+25.759
50.34	-4.355	+9.982	+29.753	+19.721	+31.684	+32.895

	LVDT-1	LVDT-2	LVDT-3	LVDT-4	LVDT-5	LVDT-6
			(Output in Volts)*			
0	5.457	2.886	4.923	4.583	5.280	4.770
9.44	5.310	2.675	4.711	4.359	5.182	4.556
19.31	5.165	2.485	4.501	4.124	5.074	4.348
29.91	4.995	2.284	4.288	3.906	4.964	4.138
39.59	4.841	2.111	4.096	3.701	4.883	3.950
49.45	4.681	1.936	3.906	3.497	4.821	3.760

* Scale factor 4.99 volts/inch (LVDT's 7 and 8 not connected because of aft plate interference).

TABLE H-3

FULL SCALE MOTOR #1 POST-CURE

PRESSURE TESTS OF NORMAL STRESS

TRANSDUCERS AT ABOUT 87°F

Transducer	Apparent Gage Sensitivity, mv/psi 12-19-72	12-28-72
N1-1	-	0.230
N1-2	-	0.233
N2-1	-	0.118
N2-2	-	-
N3-1	0.208	0.221
N3-2	0.187	0.192
N4-1	0.287	0.195
N4-2	0.259	0.223
N5-1	0.751	0.732
N5-2	0.716	0.670
N6-1	0.759	0.649
N6-2	0.759	0.743
N7-1	0.764	0.829
N7-2	0.765	0.816
N8-1	0.764	0.810
N8-2	0.751	0.789
N9-1	-	0.758
N9-2	-	0.728
N10-1	-	0.784
N10-2	-	0.740
N11-1	-	0.829
N11-2	-	0.764

TABLE H-4

POST CURE PRESSURE CALIBRATION TEST
RESULTS FOR LVDT'S 1 TO 6

Pressure (psig)	Deflection (Inches) T= 80 $\pm$ 5°F					
	*LVDT No.					
	1	2	3	4	5	6
0	0	0	0	0	0	0
9.44	.030	.042	.042	.044	.020	.043
20.0	.063	.078	.085	.091	.043	.084
29.91	.093	.120	.127	.135	.063	.127
39.59	.124	.155	.165	.176	.080	.164
49.45	.156	.190	.203	.217	.092	.202

* LVDT Nos. 7 and 8 were not installed because of pressure plate interferences.

TABLE H-5

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1 - INITIAL 5 DAYS OF 110°F CONDITIONING
(OUTPUT IN MV)

		FUNCTION							
TEMP.	TIME/DATE	N-1	N-1-1	N-2	N-2-1	N-3	N-3-1	N-4	N-4-1
64°F	1030 1-8-73	-11.90	-4.67	-4.19	-36.02	-19.15	-4.63	-8.68	-2.79
101°F	1530 1-8-73	-12.39	-5.69	-4.24	-36.37	-18.55	-2.91	-8.96	-3.61
109°F	0830 1-9-73	+12.69	-5.72	-3.43	-27.52	-17.57	-1.61	-9.08	-3.59
108°F	1545 1-9-73	+12.68	-5.69	-3.24	-24.99	-17.33	-1.35	-9.01	-3.51
108°F	0950 1-10-73	+12.59	-5.61	-2.68	-21.21	-16.49	-1.00	-8.84	-3.44
108°F	1530 1-10-73	+12.59	+5.59	-2.51	-18.19	-16.45	- .87	-8.82	-3.42
109°F	1530 1-11-73	+12.49	+5.49	-2.66	-20.94	-16.21	- .63	-8.65	-3.28
109°F	0920 1-12-73	+12.43	+5.42	-1.89	-22.07	-15.91	- .36	-8.52	-3.18
110°F	1430 1-12-73	+12.44	+5.42	-2.11	-22.31	-15.89	- .38	-8.52	-3.18
109°F	1-15-73 1505	+12.46	-5.49	-1.27	-22.19	-15.52	- .07	-8.53	-3.40

TABLE H-5 (CONTINUED)

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1 - INITIAL 5 DAYS OF 110°F CONDITIONING

(Output in mv)

		FUNCTION							
TEMP.	TIME/DATE	N-5	N-5-1	N-6	N-6-1	N-7	N-7-1	N-8	N-8-1
64°F	1030 1-8-73	-10.77	-17.99	-7.52	-5.92	-2.52	+1.32	-1.74	+1.39
101°F	1530 1-8-73	-10.39	-17.62	-8.03	-6.77	+1.18	+2.35	+1.26	-3.19
109°F	0830 1-9-73	-9.93	-17.46	-7.86	-6.54	-	+3.64	+ .70	-7.52
108°F	1545 1-9-73	-9.79	-17.37	-7.75	-6.40	-3.97	+2.23	+ .54	-8.03
108°F	0950 1-10-73	-9.35	-17.01	-7.40	-6.11	-3.31	+2.93	+ .14	-9.05
108°F	1530 1-10-73	-9.30	-17.00	-7.36	-6.06	+3.22	+3.06	+ .08	-9.32
109°F	1530 1-11-73	-9.03	-16.85	-7.07	-5.72	+2.85	+3.52	+16.94	-10.02
109°F	0920 1-12-73	-8.88	-16.80	-6.87	-5.54	-2.64	+3.78	+ .35	-10.40
110°F	1430 1-12-73	-8.87	-16.82	-6.86	-5.53	-2.62	+3.79	+ .35	-10.46

TABLE H-5 (CONTINUED)

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1 - INITIAL 5 DAYS OF 110°F CONDITIONING

(Output in mv)

		FUNCTION							
TEMP.	TIME/DATE	N-9	N-9-1	N-10	N-10-1	N-11	N-11-1	N-15	N-15-1
64°F	1030 1-8-73	-8.15	-17.10	-10.55	-14.00	-2.44	-22.33	-11.80	-5.83
101°F	1530 1-8-73	-8.54	-17.44	-10.35	-14.23	-1.73	-21.73	-12.92	-6.96
109°F	0830 1-9-73	+8.62	-17.51	-9.56	-13.79	-000	-20.97	-12.24	-7.26
108°F	1545 1-9-73	-8.50	-17.40	-9.33	-13.57	+ .27	-20.85	-14.19	-7.20
108°F	0950 1-10-73	-8.12	-17.02	-8.91	-13.22	+ .81	-20.50	-13.35	-7.04
108°F	1530 1-10-73	+8.09	+16.98	-8.83	-13.15	+ .82	-20.45	-13.85	-7.07
109°F	1530 1-11-73	+7.85	+16.73	-8.50	-12.84	+1.09	-20.31	-13.49	-7.05
109°F	0920 1-12-73	+7.68	+16.54	-8.30	-12.67	+1.25	-20.17	-14.23	-7.01
110°F	1430 1-12-73	-7.66	-16.52	-8:29	-12.65	+1.26	-20.18	-15.57	-7.01
109°F	1505 1-15-73	+7.62	-16.45	-8.32	-12.73	+1.36	-20.21	-15.75	-7.19
107°F	1500 1-22-73	-7.23	-16.05	-8.15	-12.53	+1.96	-19.61	-19.11	-7.46

TABLE H-5 (CONTINUED)

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1 - INITIAL 5 DAYS OF 110°F CONDITIONING

(Output in mv)

		FUNCTION							
TEMP.	TIME/DATE	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
64°F	1030 1-8-73	+2.469	+5.903	+2.882	-.355	-11.99	+5.075	+8.170	-3.857
101°F	1530 1-8-73	- .65	+6.78	+ .833	+2.60	-11.15	+6.27	+8.88	+1.65
109°F	0830 1-9-73	-4.411	+9.09V	+ .694	+12.03	-14.40	+5.727	+9.496	+1.513
108°	1545 1-9-73	-4.632		+ .574	+13.087	-14.91	+5.493	+9.638	+1.818
108°F	0950 1-10-73	-5.031	Data* Erratic	+ .604	+15.33	-15.70	+5.242	+9.91	+2.603
109°F	1530 1-11-73	-5.555		+ .418	+16.93	-16.45	+5.008	+9.820	+3.357
108°F	1530 1-10-73	-5.174		+ .491	+15.59	-15.92	+5.135	+9.86	+2.732
109°F	0920 1-12-73	-5.708		+ .463	+17.61	-16.67	+4.904	+9.77	+3.70
110°F	1430 1-12-73	-5.745		+ .467	+17.74	-16.73	+4.862	+9.72	+3.76
109°F	1505 1-15-73	-6.027		+ .405	+19.06	-17.60	+4.738	+9.493	+4.585

* Gage was disconnected for troubleshooting.
Gage S-2 was intermittent.

TABLE H-5 (CONTINUED)

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1 - INITIAL 5 DAYS OF 110°F CONDITIONING
(Output in mv)

		FUNCTION					
TEMP.	TIME/DATE	S-9	S-10	S-11	S-12	S-13	S-14
64°F	1030 1-8-73	-8.42	+8.99	+3.38	+1.129	-23.52	+1.110
101°F	1530 1-8-73	-8.69	+7.49	+1.92	+2.30	-17.95	- .579
109°F	0830 1-9-73	+9.09	+7.25	+1.488	+3.83	+ .021	-2.362
108°F	1545 1-9-73	+9.14	+7.36	+1.41	+4.05	+3.036	-2-617
108°F	0950 1-10-73	+8.98	+7.57	+1.65	+4.76	+8.81	-3.093
108°F	1530 1-10-73	+9.021	+7.59	+1.649	+4.899	+10.06	-3.238
109°F	1530 1-11-73	+8.951	+7.71	+1.649	+5.462	+13.78	-3.567
109°F	0920 1-12-73	+8.83	+7.73	+1.620	+5.672	+15.64	-3.734
110°F	1430 1-12-73	+8.82	+7.74	+1.61	+5.70	+1.60	-3.770
109°F	1-15-73 1505	+8.08	+7.68	+1.36	+6.16	+19.24	-4.132

TABLE H-6

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1

INITIAL 6 WEEKS OF 110°F CONDITIONING

(Output in mv)

DATE	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
1-22-73	-5.72	+ .56	+ .29	+17.97	-17.87	+4.92	+9.10	+3.82
1-31-73	-6.33	+ .63	+ .26	+17.57	-18.29	+5.15	+8.95	+3.84
2-8-73	-6.26	+ .68	+ .28	+16.56	-18.39	+5.10	+8.67	+3.26
2-16-73	-6.23	+ .65	+ .08	+15.89	-18.63	+5.22	+8.50	+2.80
2-21-73	-6.13	+ .65	+ .02	+15.54	-18.84	+5.40	+8.36	+2.58
3-2-73	-6.25	+1.2	+ .00	+15.17	-19.00	+5.30	+8.16	+2.54

	S-9	S-10	S-11	S-12	S-13	S-14
1-22-73	-8.64	+7.44	+ .94	+6.43	+17.88	-4.03
1-31-73	+8.74	+7.17	+ .55	+7.17	+18.52	-4.21
2-8-73	+9.00	+7.19	+ .49	+7.27	+17.48	-4.11
2-16-73	+9.31	+6.99	+ .28	+7.56	+16.44	-4.08
2-21-73	-9.54	+6.87	+ .11	+7.88	+16.29	-4.13
3-2-73	-9.65	+6.90	+ .12	+8.04	+16.99	-4.26

TABLE H-6 (CONT.)

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1

INITIAL 6 WEEKS OF 110°F CONDITIONING
(Output in mv)
FUNCTION

DATE	N-1	N-1-1	N-2	N-2-1	N-3	N-3-1	N-4	N-4-1
1-22-73	-12.33	-5.46	-1.07	-20.14	-15.24	- .10	-8.32	-3.28
1-31-73	+12.27	+5.72	- .79	-19.56	-15.08	+ .03	-8.19	-3.08
2-8-73	+12.55	+6.43	- .64	-19.31	-15.07	+ .00	-8.33	-2.97
2-16-72	+12.88	+6.80	- .59	-19.32	-15.12	- .15	-8.56	-3.18
2-21-73	-12.82	-6.89	- .59	-19.47	-15.18	- .29	-8.60	-3.29
3-2-73	-13.20	-7.02	- .35	-119.30	-15.09	- .27	-8.76	-3.34

DATE	N-5	N-5-1	N-6	N-6-1	N-7	N-7-1	N-8	N-8-1
1-22-73	-8.85	-17.26	-6.31	-5.59	-2.19	+4.57	+ .63	-11.04
1-31-73	-8.54	-17.17	-5.81	-4.53	+1.70	+5.22	+1.08	-11.97
2-8-73	-8.43	-17.19	-5.50	-3.02	+1.44	+5.53	+ .86	-11.56
2-16-73	-8.62	-17.47	-5.32	-4.12	+1.30	+5.76	+ .54	-11.02
2-21-73	-8.75	-17.65	-5.29	-4.13	-1.29	+5.81	+ .77	-11.16
3-2-73	-8.47	-17.50	-4.85	-4.13	- .80	+6.31	+ .64	-11.14

DATE	N-9	N-9-1	N-10	N-10-1	N-11	N-11-1	N-15	N-15-1
1-22-73	-7.23	-16.05	-8.15	-12.53	+1.96	-19.61	-19.10	-7.45
1-31-73	-6.69	-15.49	-7.94	-12.28	+2.66	-18.90	-11.45	-7.74
2-8-73	+6.41	+15.21	+7.86	+12.15	+2.73	+18.81	-14.31	-7.88
2-16-73	+6.39	+15.17	-8.01	-12.24	+2.47	-19.07	-15.69	-8.27
2-21-73	-6.27	-15.04	-8.12	-12.31	+2.68	-18.89	-14.72	-8.29
3-2-73	-5.91	-14.68	-7.97	-12.15	+2.89	-18.67	-14.30	-8.24

TABLE H-7

FLEXIBLE CASE GRAIN INTERACTION MOTOR #1

MARCH CONDITIONING DATA AT 110°F
(Output in mv)

DATE	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
3-9-73	-6.49	+1.19	-.003	+14.67	-18.89	+5.54	+8.28	+2.35
3-13-73	-5.92	+1.19	-.001	+14.79	-19.30	+5.47	+7.86	+2.29
3-29-73	-6.56	+ .68	-.06	+14.33	-18.16	+5.19	+7.38	+2.06
	S-9	S-10	S-11	S-12	S-13	S-14		
3-9-73	-9.77	+6.70	-.01	+8.38	+15.84	-4.32		
3-13-73	-9.97	+6.73	-.11	+8.52	+17.16	-4.40		
3-29-73	-10.32	+6.56	+.33	+8.30	+15.52	-4.30		

DATE	N-1	N-1-1	N-2	N-2-2	N-3	N-3-1	N-4	N-4-1
3-9-73	-13.39	-7.17	-.24	-118.61	-15.23	-.43	-8.82	-3.35
3-13-73	-13.36	-7.14	-.18	-118.21	-15.16	-.59	-8.82	-3.39
3-29-73	-12.96	-6.94	-.20	-11.17	-15.26	-.69	-8.8	-3.36
	N-5	N-5-1	N-6	N-6-1	N-7	N-7-1	N-8	N-8-1
3-9-73	-8.71	-17.63	-4.77	-3.17	-.65	+6.56	+.07	-11.41
3-13-73	-8.52	-17.68	-4.61	-4.06	-.54	+6.68	+.87	-11.27
3-29-73	-8.25	-17.56	-4.18	-2.44	+.11	+7.35	+1.03	-11.70
	N-9	N-9-1	N-10	N-10-1	N-11	N-11-1	N-15	N-15-1
3-9-73	-5.89	-14.65	-8.07	-12.21	+2.82	-18.71	-13.01	-8.50
3-13-73	-5.89	-14.65	-8.07	-12.21	+2.82	-18.71	-13.01	-8.50
3-29-73	-4.97	-13.20	-7.58	-11.34	+3.17	-17.12	-14.04	-8.23

TABLE H-8

NORMAL AND SHEAR GAGE OUTPUT DATA - MOTOR NO. 1 THERMAL CYCLING TEST (Output in mv)

Date	Temp.	Channel Function Days	N3-1 19 N-3	N3-2 20 N-3-1	N4-1 21 N-4	N4-2 22 N-4-1	N5-1 23 N-5	N5-2 24 N-5-1	N6-1 25 N-6	N6-2 1A N-6-1	N7-1 2A N-7	N7-2 3A N-7-1	N8-1 4A N-8	N8-2 24A N-8-1	N9-1 6A N-9	N9-2 7A N-9-1	N10-1 8A N-10	N10-2 9A N-10-1	N11-1 10A N-11	N11-2 11A N-11-1
3-29-73	110°		-15.26	- .69	-8.8	-3.36	-8.25	-17.56	-4.18	-2.44	+ .11	+7.35	+1.03	-11.7	-4.97	-13.20	-7.58	-11.34	+3.17	+17.12
7-19-73			+0.00	+0.00	+0.00	+0.00	+0.56	+0.01	+0.00	+0.00	+0.01	+0.00	+0.02	--	+0.05	+0.11	+0.08	+0.14	+0.02	+0.16
7-20-73			+0.00	+0.01	+0.00	+0.00	+0.00	+0.00	+0.01	+0.00	+0.00	+0.01	+0.00	--	+0.04	+0.10	+0.08	+0.11	+0.02	+0.17
7-23-73			+0.00	+0.00	+0.00	+0.00	+0.00	+0.00	+0.00	+0.00	+0.00	+0.01	+0.01	--	+0.03	+0.07	+0.05	+0.06	+0.00	+0.12
7-24-73	80	262	+0.01	+0.00	+0.02	+0.00	+0.00	+0.02	+0.01	+0.00	+0.01	+0.01	+0.01	--	+4.46	+12.69	+10.61	+12.69	+1.15	+20.30
7-25-73	80	263	+0.01	+0.02	+0.01	+0.00	+0.00	+0.02	+0.01	+0.01	+0.01	+0.01	+0.01	--	+4.66	+12.81	+11.05	+12.90	+0.59	+20.79
7-27-73	80	265	+0.05	+0.05	+0.03	+0.03	+0.56	+0.04	+0.03	-0.00	+0.00	+0.00	+0.00	+0.00	+4.85	+12.90	+11.49	+13.04	+0.32	+21.14
7-30-73	80	268	+0.02	+0.02	+0.02	+0.02	+0.01	+0.02	+0.01	-0.00	+0.01	+0.00	+0.02	+0.01	+5.19	+13.17	+11.83	+13.18	-0.85	+21.01
7-30-73	80	268.5	-23.77	-10.14	-11.83	-7.39	+0.24	+0.22	+0.18	+0.23	+0.33	+0.21	-7.66	+7.00	+6.03	+13.22	+11.50	+14.04	+0.46	+21.03
7-31-73	80	269	-24.10	-10.52	-12.03	-7.49	+0.05	+0.05	+0.05	+0.06	+0.07	+0.05	-8.03	+8.73	+4.95	+12.40	+11.18	+13.24	+0.46	+20.95
8-1-73	60	270	-24.85	-11.21	-12.42	-7.88	+0.04	+0.04	+0.04	+0.05	+0.06	+0.04	-9.03	+10.27	+5.25	+12.52	+12.52	+14.45	+2.24	+22.35
8-3-73	60	272	-24.84	-11.37	-12.54	-8.00	+0.04	+0.04	+0.04	+0.05	+0.06	+0.04	-9.44	+10.75	+5.41	+12.64	+13.02	+14.86	+2.78	+22.79
8-6-73	60	275	-24.66	-11.47	-12.67	-8.11	+0.03	+0.04	+0.03	+0.05	+0.04	+0.04	-10.05	+11.56	+5.71	+12.84	+13.77	+15.46	+3.33	+23.26
8-7-73	60	276	-24.66	-11.46	-12.61	-8.07	-0.02	+0.03	-0.02	-0.02	-0.03	-0.02	-10.09	+11.58	+5.75	+12.06	+13.89	-15.52	+3.38	+23.31
8-9-73	60	278	-24.72	-11.53	-12.66	-8.14	+0.02	+0.03	+0.01	+0.01	+0.02	+0.01	-10.46	+12.01	+5.90	+12.99	+14.12	+15.64	+3.56	+23.45
8-10-73	110	279	-24.54	-10.41	-12.43	-7.75	+0.02	+0.01	+0.02	+0.02	+0.02	+0.02	-9.23	+7.35	+5.68	+12.87	+12.79	+14.51	+0.89	+21.40
8-13-73	110	282	-23.74	-9.47	-12.28	-7.72	+0.01	+0.03	+0.03	+0.02	+0.04	+0.03	-7.87	+2.05	+6.33	+13.00	+12.09	+13.72	+0.82	+20.62
8-14-73	110	283	-22.84	-9.14	-12.48	-7.73	+0.02	+0.06	+0.00	+0.03	+0.05	+0.03	+6.56	+3.15	+6.57	+13.60	+11.78	+13.42	-2.09	+20.07
8-20-73	110	289	-22.36	-8.48	-12.11	-7.49	+0.03	+0.03	+0.01	+0.02	+0.03	+0.03	+3.39	+7.74	+6.30	+12.94	+12.28	+13.23	-4.56	+18.28
8-21-73	110	290	-21.90	-7.34	-11.86	-7.34	+0.03	+0.03	+0.02	+0.03	+0.03	+0.03	+8.08	+7.87	+6.11	+12.53	+12.17	+13.02	+4.62	+17.64
8-23-73	110	292	-21.11	-7.75	-11.49	-6.99	-16.70	+28.27	-10.04	-11.75	+3.34	+3.04	+2.33	+8.95	+6.14	+12.50	+12.33	+13.09	-5.23	+17.12
8-24-73	110	293	-21.13	-7.77	-11.43	-6.92	-18.59	+28.21	-10.01	-11.70	+3.24	+3.11	+2.14	+4.23	+6.18	+12.49	+12.48	+13.15	-5.43	+16.91
8-27-73	80	296	-22.06	-9.50	-11.53	-7.02	-17.88	+29.09	-10.24	-11.89	+6.39	+0.39	+4.15	+0.83	+7.00	+13.37	+14.15	+16.39	+3.10	+18.01
8-28-73	80	297	-22.27	-9.62	-11.63	-7.09	-17.99	+29.16	-10.40	-12.16	+6.67	+0.15	+4.45	+0.52	+7.14	+13.49	+14.42	+14.63	+2.88	+18.16
8-29-73	80	298	-22.39	-9.72	-11.71	-7.14	-18.05	+29.20	+10.53	-12.28	+6.87	-0.03	-4.73	+0.13	+7.28	+13.63	+14.68	+14.86	+2.66	+18.30
8-31-73	80	300	-22.49	-9.80	-11.70	-7.14	-18.07	+29.22	+10.63	-12.37	+7.02	-0.17	-0.20	+0.34	+7.37	+13.69	+14.92	+15.05	+2.44	+18.47
9-4-73	80	304	-22.50	-9.81	-11.70	-7.05	-18.05	+29.18	+10.64	-12.40	+6.93	-0.05	-5.57	+0.67	+7.53	+13.80	+15.15	+15.21	+2.17	+18.77
9-5-73	80	305	-22.45	-9.69	-11.58	-6.91	-17.92	+29.07	-10.54	-12.30	+6.78	+0.25	-5.42	+0.35	+7.57	+13.84	+15.10	+15.16	-2.35	+18.66
9-6-73	60	306	-23.40	-11.13	-11.61	-7.12	-18.25	+29.63	-10.41	-12.09	+8.37	-1.38	-6.34	+5.70	+7.32	+13.51	+15.90	+15.59	+0.53	+19.60
9-7-73	60	307	-23.76	-11.59	-11.83	-7.33	-18.40	+29.79	-10.85	-12.47	+9.37	-2.27	-6.90	+6.55	+7.41	+13.55	+16.48	+18.11	+0.54	+20.42
9-10-73	60	310	-24.41	-12.01	-12.08	-7.56	-18.61	+30.06	-11.67	-13.22	+10.44	-3.41	-8.06	+8.09	+7.61	+12.67	+17.66	+17.21	+2.13	+21.79

TABLE H-8 (CONT.)

NORMAL AND SHEAR GAGE OUTPUT DATA - MOTOR NO. 1 THERMAL CYCLING TEST
(Output in mv)

Date	Temp.	Channel Function Days	N3-1 19 N-3	N3-2 20 N-3-1	N4-1 21 N-4	N4-2 22 N-4-1	N5-1 23 N-5	N5-2 24 N-5-1	N6-1 25 N-6	N6-2 1A N-6-1	N7-1 2A N-7	N7-2 3A N-7-1	N8-1 4A N-8	N8-2 24A N-8-1	N9-1 6A N-9	N9-2 7A N-9-1	N10-1 8A N-10	N10-2 9A N-10-1	N11-1 10A N-11	N11-2 11A N-11-1
9-11-73	60	311	-24.57	-12.00	-12.15	-7.59	-18.62	+30.08	-11.75	-13.32	+10.83	-3.54	-8.36	+8.37	+7.74	+13.74	+17.86	+17.46	+2.31	+22.06
9-12-73	60	312	-24.67	-11.98	-12.25	-7.55	-18.82	+30.27	+12.02	-13.54	+10.92	-3.79	-8.50	+8.46	+7.84	+13.86	+18.04	+17.55	+2.56	+22.16
9-13-73	60	313	-24.64	-12.11	-12.18	-7.56	-18.83	+30.24	-11.90	+13.51	-24.06	-3.83	-8.76	+8.85	+7.92	+13.89	+18.05	+17.64	+2.74	+22.21
9-14-73	60	314	-24.77	-12.16	-12.32	-7.68	-18.99	+30.34	+12.07	-13.29	+10.97	-3.82	-9.05	+9.18	+8.02	-14.05	+18.32	+17.79	+2.93	+22.47
9-17-73	60	317	-24.61	-11.98	-12.20	-7.45	-18.64	+30.21	-11.86	-12.83	+10.73	-3.63	-9.17	+9.23	+7.96	+13.91	+18.12	+17.68	+2.94	+22.39
9-20-73	110	320	-22.69	-9.01	-9.58	-6.63	-17.67	+29.69	+10.89	-12.01	+5.79	+1.07	+6.61	-2.53	+8.64	+14.82	+15.77	+15.85	+1.22	+20.21
Approx. 70° Value for Vibration Test Checkout				-10		-7	-18		-11		-7		-5		+7		+15		+2	
D.C. Levels at time of Vibration Testing																				
12-12-73	76		-24.9	-12.1	-11.6	-8.6	-18.5		-10.6		-7.9		-8.3		-13.4		-22.6		-6.29	
		N-15-1	N-15-2	3D-1	-2	-3	-4	-5	-6											
12-12-73	76		-9.7	+45.6	+26.8	+15.3	+42.3	+57.0	+38.7											

TABLE H-8 (CONT.)

NORMAL AND SHEAR GAGE OUTPUT DATA - MOTOR NO. 1 THERMAL CYCLING TEST

(Output in mv)

Date	Temp.	Channel Function Days	12A N-15	13A N-15-1	14A 3D-1	15A 3D-2	16A 3D-3	17A 3D-4	18A 3D-5	19A 3D-6	LVDT-1	LVDT-2	LVDT-3	LVDT-4	LVDT-5	SG-1	SG-2	SG-3	LVDT-6
7-19-73			0.00	0.01	-	-	-	-	-	-									
7-20-73			+0.00	+0.01	-	-		-	-	-									
7-24-73			+0.00	+0.00	-	-	-	-	-	-									
7-25-73			+0.01	+0.00	-	-	-	-	-	-									
7-27-73			+0.01	+0.00	+0.00	+0.00	+0.01	+0.02	+0.02	+0.01						15790	15810	16162	
7-30-73			+0.01	+0.00	+0.01	+0.01	+0.01	+0.01	+0.01	+0.00						16410	16500	16740	
7-30-73			-14.28	-9.54	+62.69	+44.64	-41.95	-61.65	+82.98	+51.09									
7-31-73			-44.58	-11.11	+54.78	-36.03	-31.89	-52.33	+76.35	+43.56									
8-1-73			-52.40	-12.97	+50.26	-30.12	-23.21	-45.44	+71.59	+38.75						16485	16590	16882	
8-3-73			-59.71	-13.36	+49.31	-28.79	-21.08	-46.82	+70.43	+37.6						16460	16550	16810	
8-6-73			-56.47	-13.91	+46.39	-25.07	-16.11	-39.83	+67.14	+34.42						16530	16600	16870	
8-7-73			-65.68	-13.99	-45.44	-23.98	-14.95	-38.75	+66.78	+33.70									
8-9-73			-62.04	-14.11	+44.34	-22.61	-13.45	-37.42	+64.80	+32.09						16460	16600	16820	
8-10-73			-59.06	-14.13	+35.79	-13.65	-4.38	-28.58	+53.05	+22.51						16430	16545	16850	
8-13-73			-44.60	-13.29	+42.23	-22.90	-20.86	-41.00	+59.32	+29.24						16585	16700	17000	
8-14-73			-43.71	-13.44	+36.61	-18.40	-19.27	-37.58	+51.81	+23.14						16700	16740	16690	
8-20-73			-37.01	-12.36	+24.40	-35.21	-42.39	-56.67	+67.37	+38.30						17170	17340	17600	
8-21-73			-35.96	-11.98	+50.81	-35.48	-42.72	-56.55	+66.90	+38.43						17370	17430	17700	
8-23-73			-36.65	-10.98	+50.49	+35.48	-43.09	-56.56	+66.47	+38.18									
8-24-73			-36.19	-10.79	+50.56	-35.70	-43.50	-56.81	+66.53	+38.26						17130	17240	17520	
8-27-73			-23.68	-10.72	+55.83	-37.58	-37.91	-56.75	+74.02	+43.78						16860	16980	17240	
8-28-73			-44.63	-10.86	+53.61	-35.11	-34.25	-53.76	+71.59	+41.40						16780	16840	17100	
8-29-73			-46.93	-10.93	+52.23	-33.55	-31.83	-51.83	+70.05	+39.90						16660	16730	17070	
8-31-73			-47.29	-11.05	+50.50	-31.65	-28.91	-49.48	+68.14	+38.06						16860	16980	17260	
9-4-73			-48.07	-11.18	-	-31.35	-27.97	-48.94	+67.48	+37.79						16940	17080	17360	
9-5-73			-46.21	-10.94	+51.92	-33.06	-30.11	-50.84	+68.83	+39.29	5.147	2.592	4.541	5.106	3.929	16870	16950	17250	4.476
9-6-73			-45.32	-10.79	+58.97	-40.10	-35.44	-57.01	+79.35	+47.31	5.066	2.406	4.421	5.233	3.825	16630	16750	17000	4.353
9-7-73			-49.26	-11.28	+55.57	-35.95	-29.17	-51.94	+75.93	+43.69	4.837	2.193	4.161	5.169	3.624	16450	16490	16820	4.114
9-10-73			-52.74	-12.19	+51.53	-30.82	-21.08	-45.52	+71.36	+39.28	4.644	1.962	3.908	5.196	3.430	16810	16920	17220	3.860
9-11-73			-58.22	-	+50.86	-29.86	-19.89	-44.45	+70.54	+38.44	4.623	1.935	3.892	5.202	3.409	16740	16835	17100	3.828
9-12-73			-59.14	-12.51	+49.23	-28.15	-17.87	-42.63	+68.76	+36.93	4.587	1.903	3.836	5.183	3.378	16630	16720	17020	3.790
9-13-73			-62.79	-12.49	+48.51	-27.27	-16.68	-41.63	+67.81	+35.97	4.585	1.894	3.833	5.193	3.371	16650	16770	17020	3.778
9-14-73			-63.07	-12.58	+47.69	+26.38	+15.86	+40.86	+67.03	+35.12	4.575	1.880	3.818	5.196	3.360	16230	16280	16750	3.764
9-17-73			-65.53	-12.66	+44.22	-22.76	-12.03	-37.13	+63.30	+31.55						16900	16610	16520	
9-20-73			-63.89	-12.08	+26.99	+6.98	+1.22	-23.63	+42.48	+12.40									

TABLE H-8 (CONT.)

NORMAL AND SHEAR GAGE OUTPUT DATA - MOTOR NO. 1 THERMAL CYCLING TEST

(Output in mv)

	Temp.	Channel Function Days	1 S-1	2 S-2	3 S-3	4 S-4	23A S-5	6 S-6	7 S-7	8 S-8	9 S-9	10 S-10	11 S-11	12 S-12	13 S-13	14 S-14	15 N-1-1	16 N-1-2	17 N-2-1	18 N-2-2
3-29-73	110																-12.96	-6.94	- .20	-11.17
7-18-73			+0.00	+0.00	+0.01	+0.00	+0.07	-0.02	-0.01	+0.02	+0.01	+0.01	-0.00	-0.01	-3.07	-0.01	-0.14	-0.06	+0.01	-0.13
7-20-73			+0.01	+0.02	+0.02	+0.01	+0.09	-0.03	-0.01	+0.02	+0.00	+0.00	+0.00	-0.02	-3.12	-0.02	-0.15	-0.07	-0.00	-0.11
7-23-73			+0.01	+0.03	+0.01	-0.03	+0.05	-0.03	+0.02	+0.00	+0.01	+0.00	+0.00	+0.00	+1.78	+0.00	+0.08	+0.05	+0.00	-0.07
7-24-73	80	262	+0.01	+0.00	+0.01	+0.01	+10.28	-1.23	-1.95	+1.57	+0.01	+0.00	+0.07	+2.21	Over/ Scale	-2.59	-18.19	-10.98	-4.81	-0.38
7-25-73	80	253	+0.00	+0.02	+0.00	+0.02	+9.89	+1.73	+2.00	+2.16	+0.03	+0.01	+0.25	+2.11	"	-1.79	-18.29	-11.08	-4.88	-0.40
7-27-73	80	265	+0.02	+0.06	+0.00	+0.06	+9.62	-1.51	-1.98	+2.61	+0.04	+0.01	+0.25	+1.95	"	-1.69	-18.41	-11.21	-4.94	-0.27
7-30-73	80	268	+0.01	+0.03	+0.01	+0.03	+10.45	-1.65	-2.03	+1.64	-0.01	+0.00	-0.12	-2.21	"	-2.61	-18.34	-11.16	-4.95	-0.31
7-30-73	80	268.5	+ .12	+ .28	+0.37	+0.21	+7.55	+.002	+2.20	+3.00	+0.06	+6.49	+0.54	+1.81	357.7	-1.62	-18.61	-11.38	-4.88	-0.21
7-31-73	80	269	+ .04	+0.11	+0.09	+0.11	+6.87	-1.32	-3.09	+4.35	-0.01	+5.59	+0.99	-1.88	Over/ Scale	+0.52	-18.60	-11.33	-4.25	-0.42
8-1-73	60	270	+0.03	+0.05	+0.07	+0.06	+5.62	-3.07	-4.03	+4.31	+0.01	+2.76	+4.18	-0.83	"	+3.06	-19.03	-11.73	-4.30	-0.42
8-3-73	60	272	+0.03	+0.05	+0.06	+0.06	+5.37	-3.43	-4.19	+4.11	+0.01	+2.02	+4.97	-0.54	"	+3.75	-19.18	-11.87	-4.33	-0.03
8-6-73	60	275	+0.03	+0.03	+0.05	+0.04	+4.93	-3.89	-4.32	+3.60	+0.03	+0.95	+6.01	+0.01	"	+4.90	-19.41	-12.06	-4.15	-0.43
8-7-73	60	276	-0.02	-0.02	+0.03	-0.03	+4.89	-3.85	-4.16	+3.45	-0.12	-0.88	+5.96	-0.15	"	-5.07	-13.44	-12.06	-4.11	-0.95
8-9-73	60	278	+0.00	+0.01	+0.03	+0.03	+4.83	-3.73	-4.23	+6.40	+0.02	+ .90	+5.79	+0.47	"	+5.29	-19.62	-12.21	-4.10	-0.45
8-10-73	110	279	+0.00	+0.08	+0.03	+0.01	+6.46	-3.15	-2.50	+1.66	+0.09	+1.94	+2.74	+0.33	"	+1.61	-19.30	-11.98	-4.01	-0.46
8-13-73	110	282	+0.00	+0.01	+0.05	+0.01	+9.62	-1.87	-1.79	+0.95	+0.04	+4.93	+0.58	+1.40	"	-0.00	-19.09	-11.73	-4.44	-0.46
8-14-75	110	283	+0.02	+0.06	+0.05	+0.01	+12.39	-2.94	-2.76	+0.34	+0.10	+4.56	+0.02	+4.62	"	-5.10	-18.90	-11.67	-4.39	-0.48
8-20-73	110	289	+0.02	+0.00	+0.04	+0.02	+13.45	-3.37	-3.47	-0.49	+0.04	+6.14	-0.62	+7.60	"	-7.10	-18.16	-11.23	-3.37	-0.44
8-21-73	110	290	+0.01	+0.00	+0.04	+0.02	+13.12	-3.92	-3.38	-0.53	+0.03	+6.02	-0.54	+7.45	"	-0.95	-17.62	-10.84	-3.25	-0.43
8-23-73	110	292	-6.99	+0.51	Over/ Scale	+12.57	+13.20	+4.02	+3.45	-0.81	-12.50	+6.05	+0.38	+7.61	"	-7.04	-17.37	-10.83	-2.23	-0.09
8-24-73	110	293	-7.05	+0.55	"	+12.72	+13.22	-4.04	-3.47	-0.94	-12.51	+6.11	+0.34	+7.63	"	-7.06	-17.34	-10.55	-2.16	-0.08
8-27-73	80	296	-1.83	+1.32	"	+2.38	+8.10	-2.14	-1.87	+2.80	-11.00	+5.91	+0.17	+2.76	"	-2.79	-17.93	-11.00	-3.53	-0.03
8-28-73	80	297	-1.80	+1.38	"	+6.69	+7.96	-2.27	-1.82	+2.81	+10.77	+5.36	+0.72	+2.43	"	-2.25	-18.09	-11.16	-3.64	-0.06
8-29-73	80	298	-1.83	+1.50	"	+1.29	+7.88	+2.35	+1.81	+2.83	+10.63	+5.01	+1.10	-2.11	"	-1.83	-18.18	-11.21	-3.69	-0.04
8-31-73	80	300	-1.96	+1.65	"	+0.90	+7.87	+2.48	+1.81	+2.75	+10.51	+4.54	+1.41	-1.77	"	-1.31	-18.33	-11.30	-3.71	-0.05
9-4-73	80	304	-2.38	+1.63	"	+0.92	+8.20	-2.58	-1.97	+2.57	+10.59	+4.21	+1.40	+1.62	"	-1.28	-18.44	-11.35	-3.74	-0.03
9-5-73	80	305	-2.71	+1.39	"	+1.41	+8.47	-2.44	-1.72	+2.32	-10.81	+4.62	+0.95	-1.83	"	-1.84	-18.35	-11.22	-3.67	-0.27
9-6-73	60	306	+0.95	+3.29	"	+2.74	+5.98	+1.86	+2.28	+5.13	+9.31	+4.46	+2.23	+0.83	"	+1.31	-18.63	-11.33	-3.62	-0.40
9-7-73	60	307	+0.97	+4.49	"	-3.29	+5.26	-2.99	-3.01	+5.01	+8.07	+2.60	+4.19	+0.47	"	+0.04	-18.89	-11.61	-3.76	-0.84
9-10-73	60	310	+0.47	+5.50	"	-3.07	+4.41	-4.42	-3.94	+4.04	-6.68	+0.28	+7.03	+0.54	"	+5.52	-19.38	-12.01	-3.96	+0.32
9-11-73	60	311	+0.30	+5.70	"	+3.05	+4.39	+4.49	+6.02	+3.75	+6.44	+0.21	+7.28	+0.71	"	+5.93	-19.48	-12.14	-3.95	+0.46
9-12-73	60	312	+0.28	+5.72	"	+3.05	+4.34	+4.55	+4.08	+3.68	+6.50	+0.23	+7.33	+0.79	"	+6.23	-19.69	-12.15	-4.12	+0.35

TABLE H-8 (CONT.)

NORMAL AND SHEAR GAGE OUTPUT DATA - MOTOR NO. 1 THERMAL CYCLING TEST

(Output in mv)

	Temp.	Channel Function Days	1 S-1	2 S-2	3 S-3	4 S-4	23A S-5	6 S-6	7 S-7	8 S-8	9 S-9	10 S-10	11 S-11	12 S-12	13 S-13	14 S-14	15 N-1-1	16 N-1-2	17 N-2-1	18 N-2-2
9-13-73	60	313	+0.22	+5.40	Over/ Scale	+2.98	+4.31	+4.52	+3.98	+3.44	-6.46	+0.23	+7.32	+0.86	Over/ Scale	+6.36	-19.79	-12.20	-4.12	-0.31
9-14-73	60	314	+0.24	+5.86	+392.16	+3.02	+4.29	+4.46	-4.04	+3.40	+6.64	+0.24	+7.10	+1.09	"	+6.32	-19.98	-12.49	-4.16	-0.78
9-17-73	60	317	-0.27	+5.64	Over/ Scale	-2.83	+4.40	-4.26	-3.72	+3.22	+6.71	+0.22	+6.79	+1.51	"	+6.35	-19.93	-12.38	-4.13	-0.94
9-25-73	110	320	-6.60	+1.42	"	14.51	+11.30	+3.61	+2.62	+1.33	+10.61	+3.06	+1.93	+1.62	"	-2.60	-19.37	-11.82	-3.65	-0.84
Approx. 70°F Value for Vib. Test Checkout			-2	+2	+7	+1	+8	-4	-4	+3	+11	+4	+1 +4	-2	-30	-1 +4		-11		-5

D.C. Levels at time of vibration testing on 12 December 1973 T = 76°F

	1 S-1	2 S-2	3 S-3	4 S-4	23A S-5	6 S-6	7 S-7	8 S-8	9 S-9	10 S-10	11 S-11	12 S-12	13 S-13	14 S-14	15 N-1-1	16 N-1-2	17 N-2-1	18 N-2-2
	-6.0	+5.8	8.70	9.6	-1.89	+3.62	+5.18	+16.2	-8.5	+ .91	+3.61	+1.56	-365	+5.38		-12.6	-4.8	

APPENDIX I

SUMMARY OF VIBRATION TEST RESULTS

SUMMARY OF VIBRATION TEST RESULTS

A. OBJECTIVES

The overall objective of the thrust and transverse axis vibration survey tests of Minuteman III Stage III Motor No. 1 was to characterize the dynamic response functions resulting from the application of controlled constant acceleration and constant force sinusoidal input excitations.

Emphasis was directed in this phase of the test program towards the acquisition of high quality dynamic input and response data throughout the test frequency range of 10 to 300 cps. Special care was taken to ensure that the sinusoidal acceleration and force input excitation functions have a minimum wave form distortion over the specified test frequency range.

The specific objectives of the vibration survey tests of Motor No. 1 were:

1. To record on a magnetic tape recorder the dynamic responses of all designated dynamic transducers to constant acceleration and constant force sinusoidal excitation functions to be applied at a slow sweep rate of one octave/min. to the thrust (Y) and transverse (Z) axis of the motor over a test frequency range of 10 to 300 cps.

2. To identify all significant resonant and anti-resonant frequencies of the thrust (Y) axis and transverse (Z) axis motor test configurations occurring in the 10-300 cps test frequency range.

3. To determine the mode shapes and corresponding dynamic normal and shear stress measurements at each significant resonant and anti-resonant frequency detected during the Y and Z axis surveys.

The detailed test procedures for conducting the low input level, constant acceleration and constant force survey tests in the Y (thrust) and Z (transverse) axis of the full scale third stage Minuteman motor are specified in test plan 1826-26-TP.

B. DESCRIPTION OF MOTOR TEST CONFIGURATIONS

1. General

During the thrust (Y) axis and the transverse (Z) axis survey tests the motor (including a fired nozzle attached for c.g. considerations) was suspended in a horizontal attitude from an overhead cable support system. These cables were attached to motor handling rings that are bolted to the forward and aft motor skirts. The angular orientation of the motor during both the Y and Z axis survey tests was such that the 0° - 180° (X) axis of the motor is vertical (perpendicular to the floor) with the 0° location of the motor in the "down" position.

2. Thrust (Y) Axis Test Configuration

The vibration survey tests of the Y-axis test configuration of the motor were conducted with the use of one Ling Model A-249 electrodynamic exciter. The Y axis vibratory excitation was applied to the motor forward skirt through a rigid conical drive fixture that was bolted to the motor forward skirt. An impedance head was positioned between the moving element of the electrodynamic exciter and the small-diameter end of the conical drive fixture. A schematic drawing of the Y-axis test setup is shown in Figure I-1.

3. Transverse Z (90° - 270°) Axis Test Configuration

The vibration survey tests of the Z-axis motor test configuration was conducted with the use of two Ling Model A-249 electrodynamic exciters. One exciter was attached to the forward skirt motor handling ring and the other was attached to the aft skirt motor handling ring. The Z-axis vibratory excitation was applied transversely to the motor through the two motor skirt handling rings along an axis that is parallel to the 90° - 270° axis of the motor. An impedance head (or dynamic force gage) was installed between each exciter moving element and motor skirt vibration input point. A schematic drawing of the test setup used in conducting the transverse Z-axis vibration survey tests of motor No. 1 is shown in Figure I-2.

Both in-phase and out-of-phase Z-axis vibration survey tests were conducted by operating the two exciters in-phase and 180° out-of-phase with respect to each other.

C. INSTRUMENTATION AND DATA ACQUISITION REQUIREMENTS

1. Dynamic Instrumentation Requirements

a. Thrust (Y) Axis Vibration Survey Tests

Forty-six channels of dynamic response data were continuously recorded on a magnetic tape recorder and oscillographs during the Y-axis vibration test. The channels of Y-axis dynamic response data and dynamic transducers were:

· Impedance Head	1 Channel
· Accelerometers	20 Channels
· Normal Stress Gages	11 Channels
· Shear Stress Gages	14 Channels

Detailed descriptions of the locations of the dynamic transducer during the Y-axis vibration survey tests are shown in Figure I-1.

b. Transducer Z-Axis Vibration Survey Tests

Forty-six channels of dynamic response data were continuously recorded on a magnetic tape recorder and oscillographs during the Z-axis vibration survey test. The channels of Z-axis dynamic response data were the same as for the Y-axis tests. The locations of the dynamic transducers during the Z-axis vibration survey tests are shown in Figure I-2.

D. TESTS

1. Thrust Axis

The first series of tests to be conducted was in the thrust axis. The types of vibration tests conducted in the thrust axis of the motor were listed as follows:

Run 001	10-100 HZ Sweep, 5K Constant Force
001A	10-100 HZ Sweep, 1K Constant Force
002	10-300 HZ Sweep, .5 g Constant Acceleration
003	30-56 HZ Dwell, .5 g Constant Acceleration
004	10-300 HZ Sweep, 1 g Constant Acceleration
005	44 HZ Dwell, 20 sec, 1 g Constant Acceleration
Run 006	36.7 HZ Dwell, 20 sec, 1 g Constant Acceleration
007	10-27 HZ at 1.5 g (Wave form was bad)
008	10-300 HZ Sweep, 1.5 g Constant Acceleration
009	44.4 HZ Dwell, 1.5 g Constant Acceleration
010	38.4 HZ Dwell, 1.5 g Constant Acceleration
011	10-59 HZ, (Bad cycle), 2 g Constant Acceleration
012	30-37 HZ, Rerun, 2 g Constant Acceleration
013	30-38 HZ, Rerun, 2 g Constant Acceleration
014	46-306 HZ Sweep, 2 g Constant Acceleration
015	45.1 HZ Dwell, 2 g Constant Acceleration

Results of the series of survey tests conducted in the transverse axis indicated that the propellant axial shear mode is between 36 to 44 HZ.

The sine sweep survey test consisted of one sine sweep from 10 to 300 cps using a logarithmic sweep rate of one octave/min. The resonant frequency dwell test consisted of 20-second discrete frequency dwell test conducted at a certain acceleration input and at the resonant frequency determined during the sine sweep survey test. The input control accelerometers for all constant acceleration tests were accelerometers G-30-Z and G-31-Z.

2. Transverse Axis

The series of survey tests conducted in the transverse axis were listed in the following test sequence (a total of 21 runs were completed).

Run Nos.	Z (Transverse Axis)
016	1 g sine sweep survey (10-300 Hz)
017	(No oscillator data - just repeat for accel. plots)
017	1 g sine sweep survey (103-00 Hz) - the repeat 1 g sweep was required in order to plot accelerometer data from tape - D.C. to frequency conditioning amplifier overloaded on run 016 resulting in compressed information.
018	1,000# force sine sweep (10-300 Hz)
019	32.7 Hz at 1,000# force (anti-resonance)
020	45.7 Hz at 1 g (propellant ray)
021	77.5 Hz at 1,000#/per shaker force (principal resonance)
022	77.5 Hz at 1.0 g
023	123.7 Hz at 800#/per shaker force (propellant due to nozzle)
024	123.7 at 1 g
025	1,000# force sine sweep (180° out of phase - 10-300)
026	1 g sine sweep survey (180° out of phase - 10-300)
027	40.9 Hz at 1 g (180° out of phase)
028	82.3 Hz at 1 g (180° out of phase)

Run Nos.	Z (Transverse Axis)
029	Nozzle - 115.4 Hz at 1 g (180° out of phase)
030	Nozzle - 153.2 Hz at 1 g (180° out of phase)
031	2 g sine sweep survey (in phase) 10-300 Hz
032	44.6 Hz at 2 g (in phase)
033	110.4 Hz at 2 g (in phase)
034	73.8 Hz at 2 g (in phase)
035	124.8 Hz at 2 g (in phase)
036	124.8 Hz - G30Z at 1 g, G31Z at 2 g (in phase)

The large number of discrete frequency runs made during the transverse axis testing were required to provide additional data to define the dynamic characteristics of the motor and its components. As previously described, 15 runs were conducted in the Y (thrust) axis.

The vibration testing of full scale Motor No. 1 was essentially conducted in accordance with test plan 1826-26-TP, dated September 1972. Deviations in procedure are described in the following paragraph.

The force transducers available for the test (Endevco Model 2110 impedance heads) have a 10,000 pound maximum dynamic range. During the 1/2 g pre-run tests, it was determined that the force necessary to produce 1/2 g acceleration was approximately 7,000 lbs, therefore the force to produce 1 g acceleration would be almost double and exceed the capacity of the 10,000 impedance head. To prevent damage, therefore, the transducers were removed after completion of the 1/2 g constant acceleration and the constant force surveys in the Y axis and after the 1 g survey in the Z axis.

E. VIBRATION TEST DATA

Typical response data obtained from the normal stress and shear gages during the vibration runs are presented in Figures I-3 through I-5. Similar data for the accelerometers are given in Figures I-6 through I-11. The complete data package from the vibration testing is located in the documentary file.

Sine sweep survey tests were conducted over a 10 to 300 Hz frequency range at each of the following acceleration levels: 0.5 g, 1.0 g, 1.5 g and 2.0 g. Input excitation was controlled using accelerometer G-8Y, mounted on the forward skirt of the motor adjacent to the drive ring. The data plots indicate primary propellant responses occurred in the 45 Hz fre-

quency range in the thrust (Y) axis. Figure I-6 shows the relative responses on the chamber near the forward "Y" joint (G-10Y), at Station 26 (G-11Y), and near the aft "Y" joint (G-12Y). Figures I-7 through I-9 show the propellant response (solid line) versus the chamber response (dotted line) at Stations 38, 26 and 9 for a 1 g input at G-8Y. The "Q" of the propellant response at Station 38, 26 and 9 are approximately 5.6, 3.6, and 3.2 respectively. Typical responses at the igniter boss (G-13Y) and on the aft motor dome (G-14Y) are illustrated in Figures I-10 and I-11. The igniter boss shows a Q of 14, and the aft dome shows a Q of 2.8.

The shear stresses measured at 2 g longitudinal acceleration during the resonance frequency dwell at 45 Hz (Table I-1) show a gradual increase in magnitude from the aft end where the grain is attached to the case to the forward end where the end is booted and free to move. It is interesting to point out that during the 1.5 g survey tests, two frequencies were of interest, 38 Hz and 45 Hz. It was estimated that the 38 Hz is an anti-resonance frequency and the 45 Hz is the principal resonance frequency of the grain.

The normal and shear gage outputs for the vertical transverse vibration mode for runs No. 020 and No. 032, which were both at the resonant frequency of approximately 45 Hz in this mode of vibration are shown in Figure 47 in the text. The two runs were at $\pm$ 1 g and $\pm$ 2 g acceleration levels and the increase in signal with g level is apparent. However, most of the gages do not give a linear response as a function of acceleration. This may be because of the slight shift in frequency from 45.7 Hz to 44.6 Hz from the 1 g to the 2 g run.

The data from the 3D gage situated near the head end flap termination are also given in Figure 47 of Volume I. These data seem to correspond fairly well with the other gage data in similar locations. The large output from shear gage SH-13 and from the 3D gage in the τ_{rz} plane suggests that there is a good deal of motion of the star points in this mode of vibration. There also seems to be some coupled fore and aft motion in the motor.

Figure 48 in the text shows similar data from the axial vibration tests. These data were measured during runs 05 and 09 at 1.0 and 1.5 g level respectively. The resonant frequency in this direction was 44.4 Hz.

These data seem very good in the sense that the stresses from the gages show a maximum response at the aft end adjacent to the knuckle area. The stress becomes smaller along the mid section of the grain and are smallest just short of the end of the forward flap. The axial shear stresses are generally the largest stresses along the center of the motor but around the aft end dome, the shear stresses gradually change into fore and aft tension/compression stresses. Thus at the rear end of the motor, the normal stresses from gages N2 and N3 situated at the knuckle are the most significant. Gages N1 and N4 further round the aft dome exhibit smaller tensile/compressive stresses and after this point the major stresses are the shear stresses. As might be anticipated the greatest shear stress occurs at the flap termination and is noted by gage SH-13. This stress is approximately 1.5 x the shear stress at the middle of the grain (gages SH-9 and SH-11).

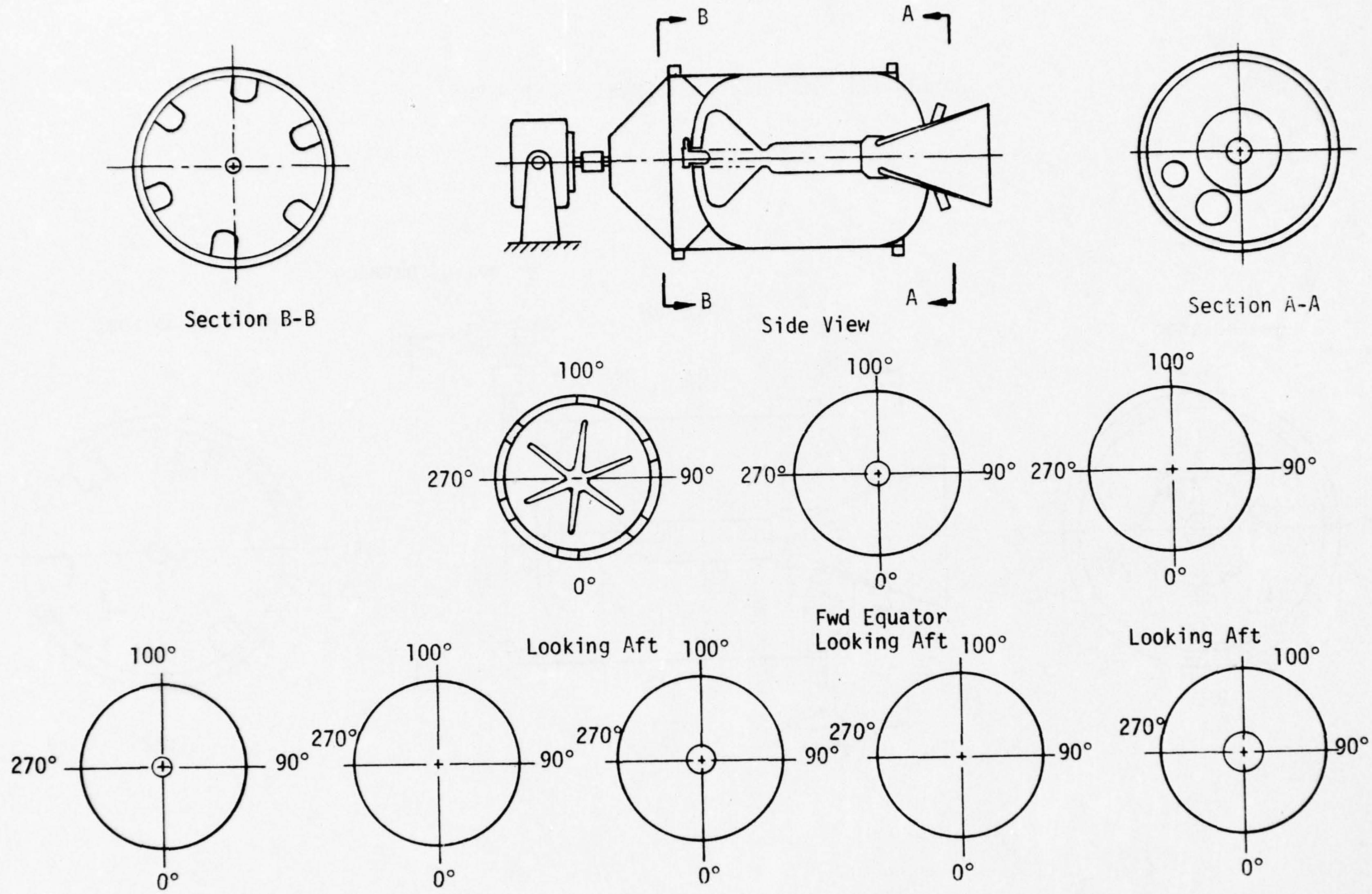


FIGURE I-1. THRUST (Y) AXIS TEST SET-UP

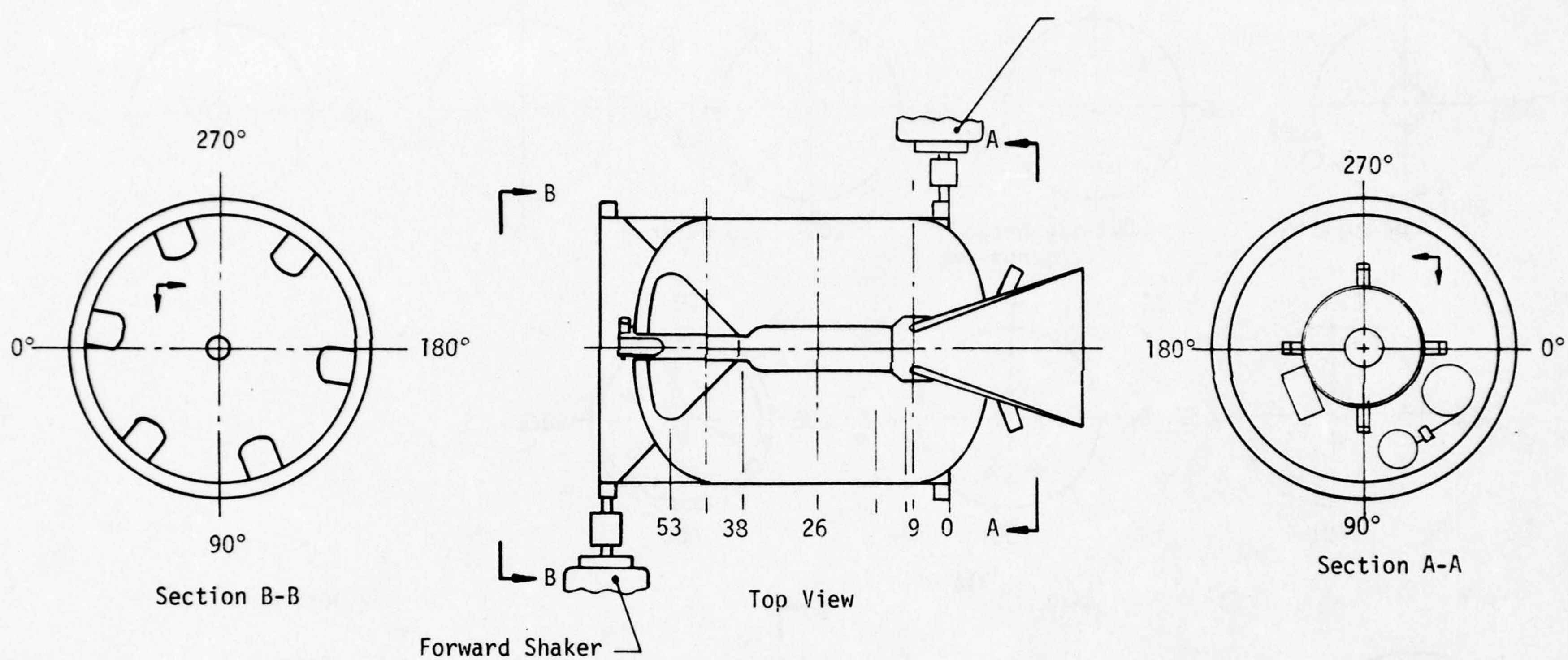


FIGURE I-2. TRANSVERSE (Z) AXIS TEST SET-UP

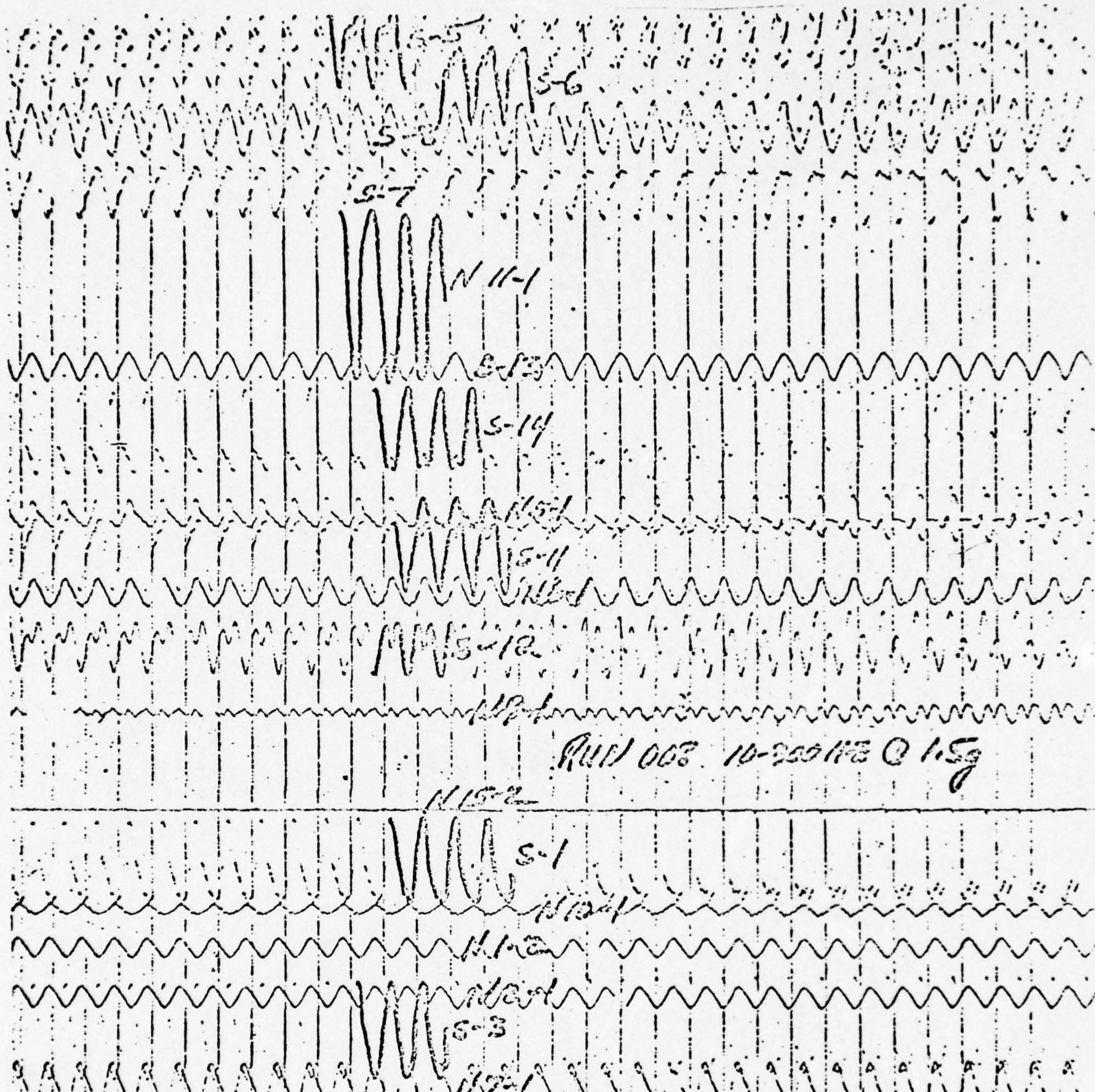


FIGURE I-3. STRESS GAGE RESPONSE DATA FOR 10 TO 300 HZ SWEEP AT 1.5 G ACCELERATION

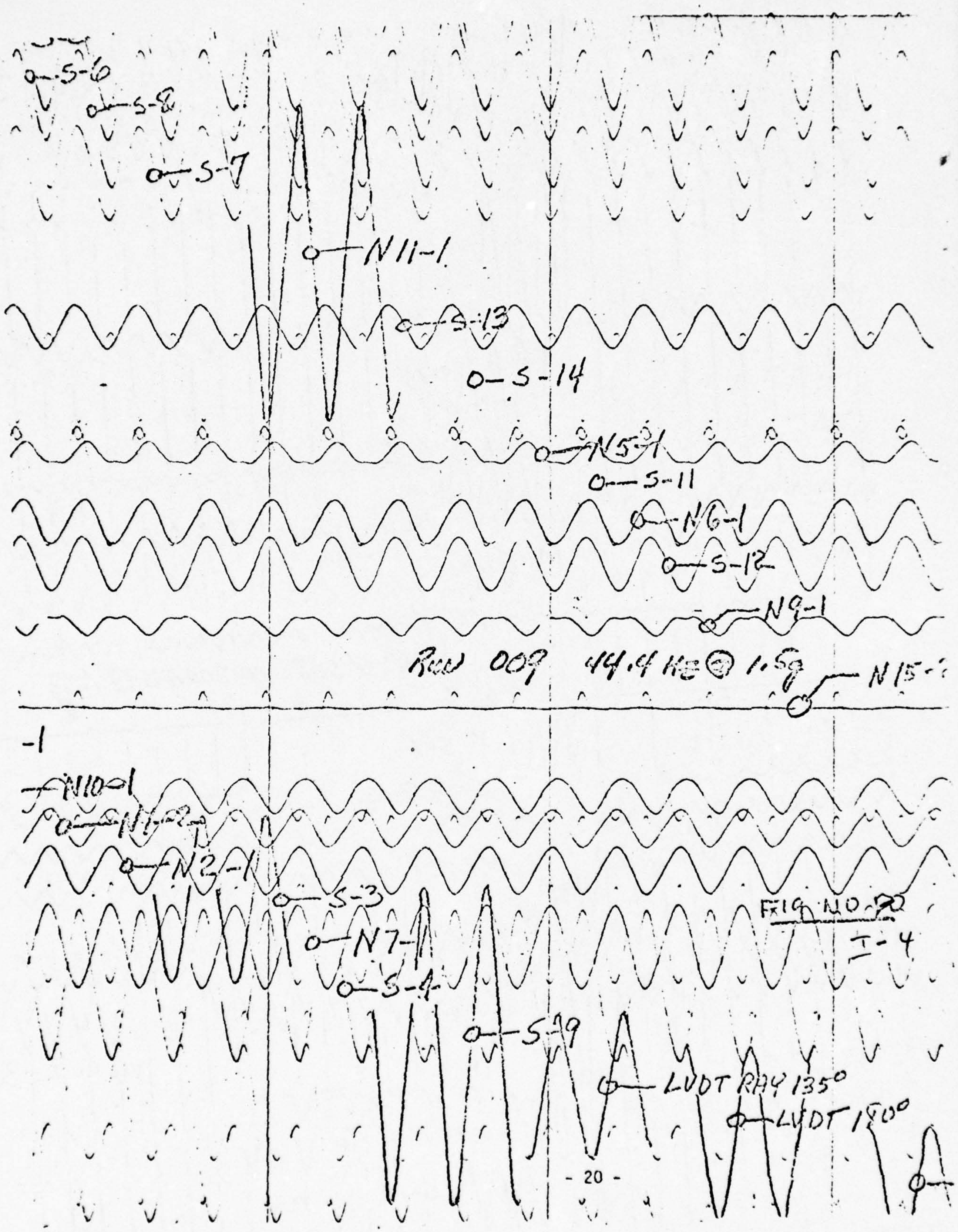


FIGURE I-4. STRESS GAGE RESPONSE DATA FOR 44.4 HZ DWELL TEST AT 1.5 G CONSTANT ACCELERATION

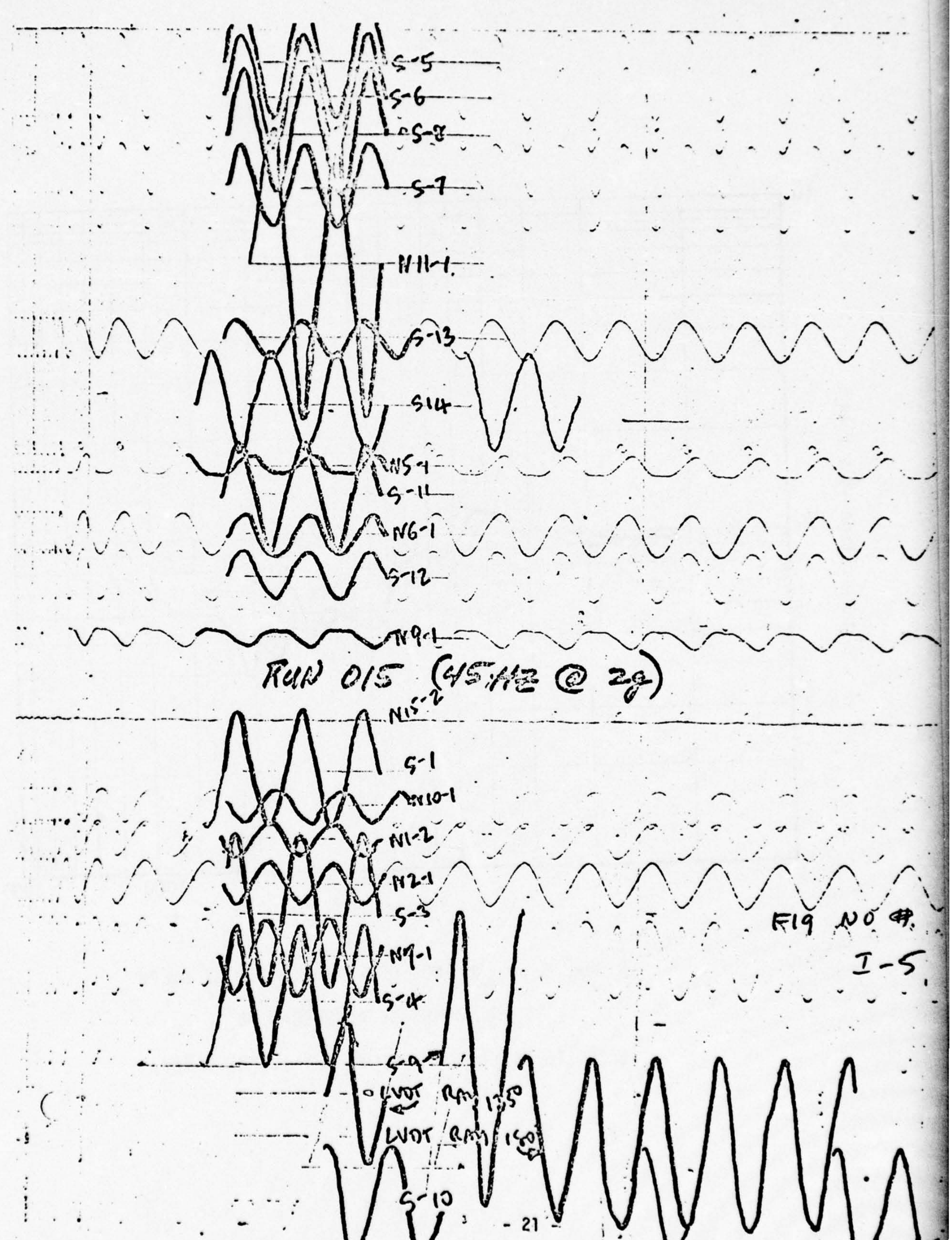


FIGURE I-5. STRESS GAGE RESPONSE DATA FOR 45.1 HZ DWELL TEST AT 2 G CONSTANT ACCELERATION

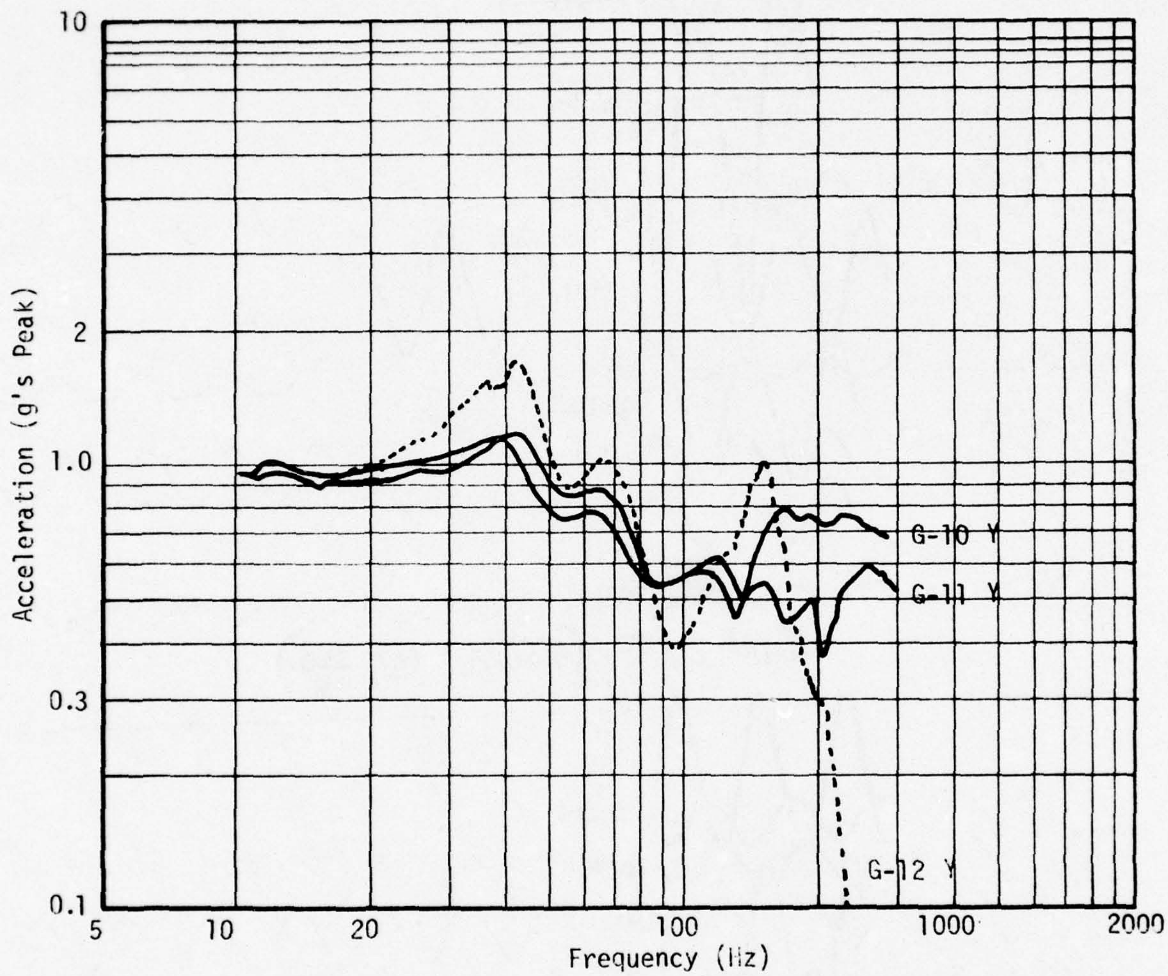


FIGURE I-6. RUN NO. 004 - 10 TO 300 HZ SWEEP

AT 1G CONSTANT ACCELERATION

(ACCELEROMETER NOS. G-10Y, G-11Y, AND G-12Y)

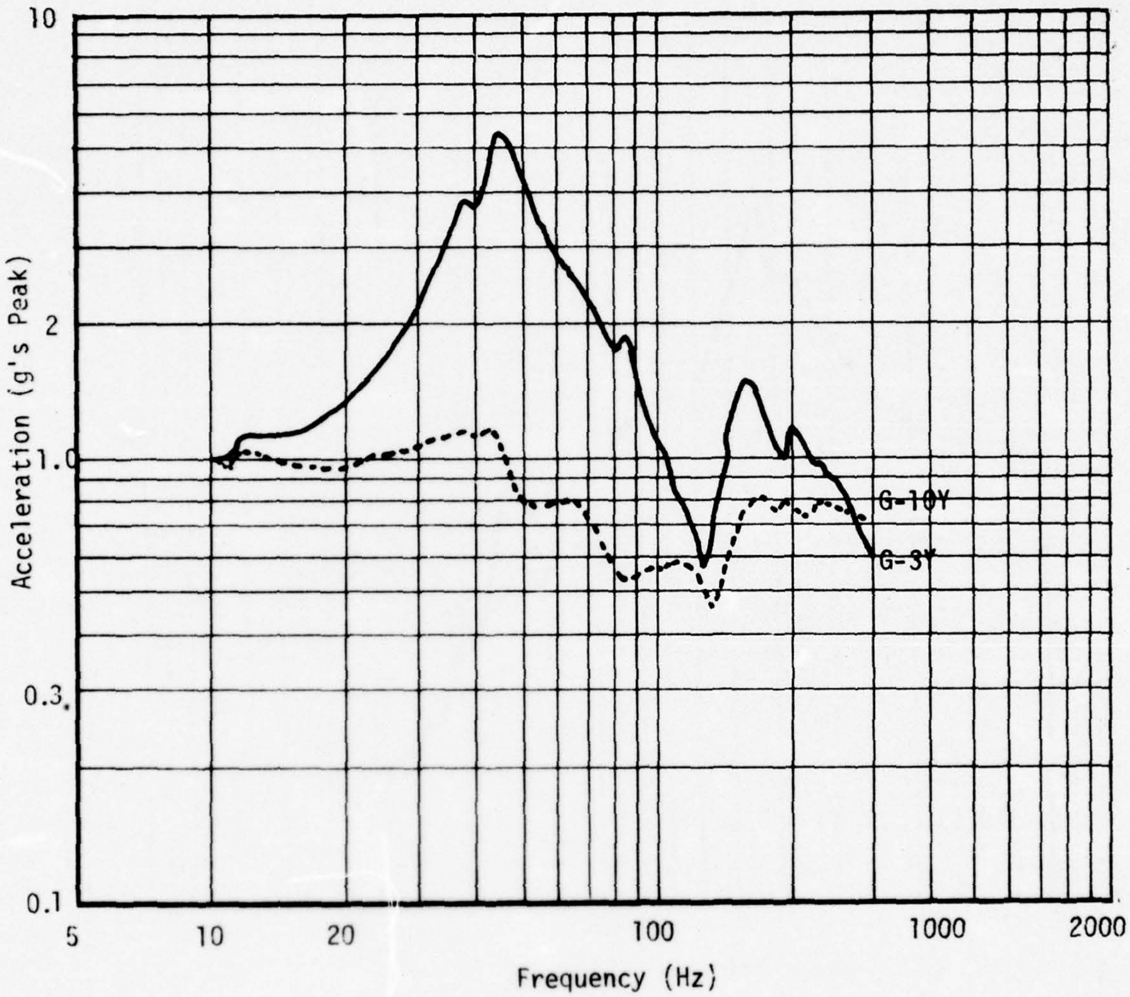


FIGURE I-7. RUN NO. 004 - 10 TO 300 HZ SWEEP

AT 1G CONSTANT ACCELERATION

(ACCELEROMETER NOS. G-3Y AND G-10Y)

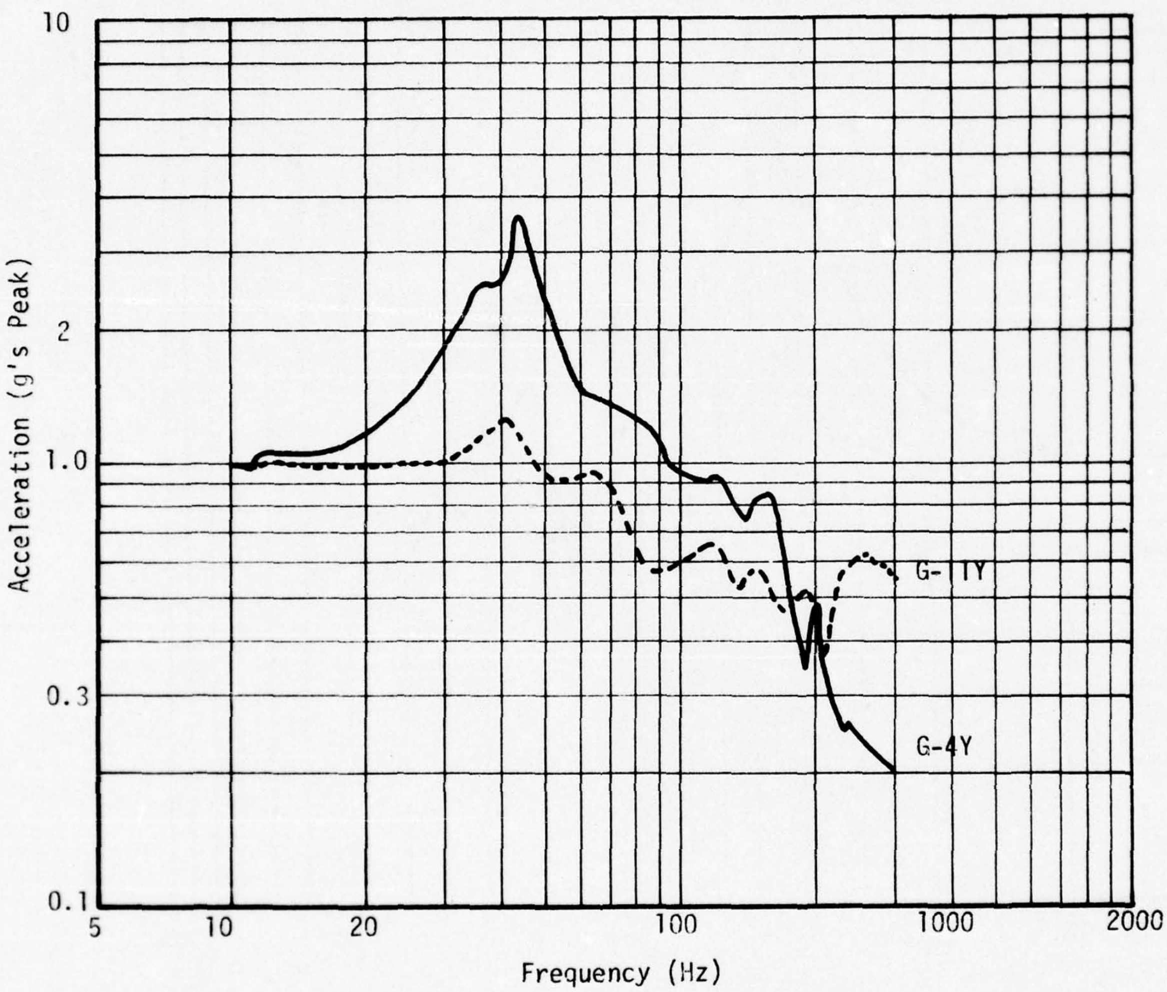


FIGURE I-8. RUN NO. 004 - 10 TO 300 HZ SWEEP

AT 1G CONSTANT ACCELERATION

(ACCELEROMETER NOS. G-4Y AND G-11Y)

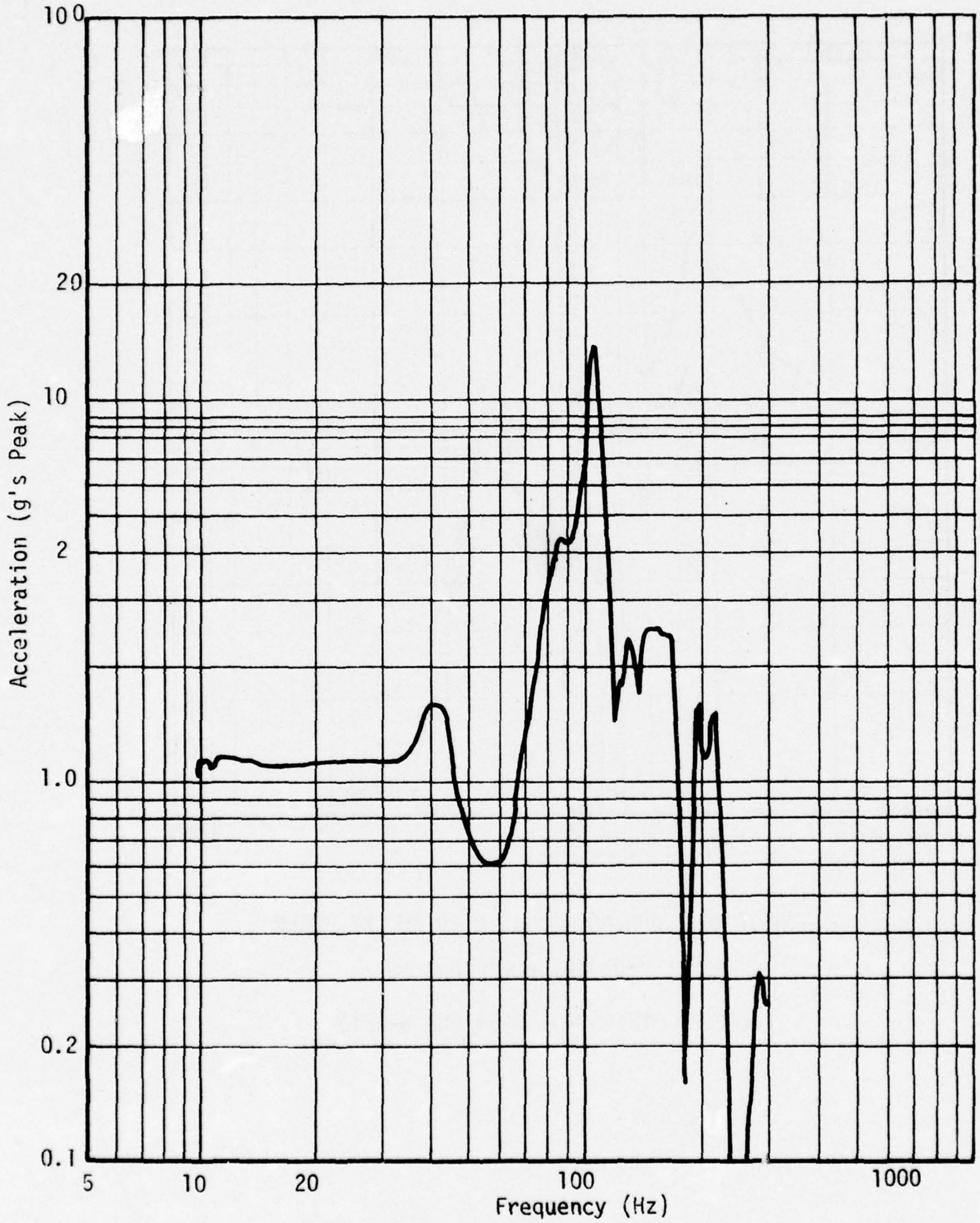


FIGURE I-9. RUN NO. 004, 10 TO 300 HZ SWEEP
AT 1G CONSTANT ACCELERATION

(ACCELEROMETER NO. G-13Y)

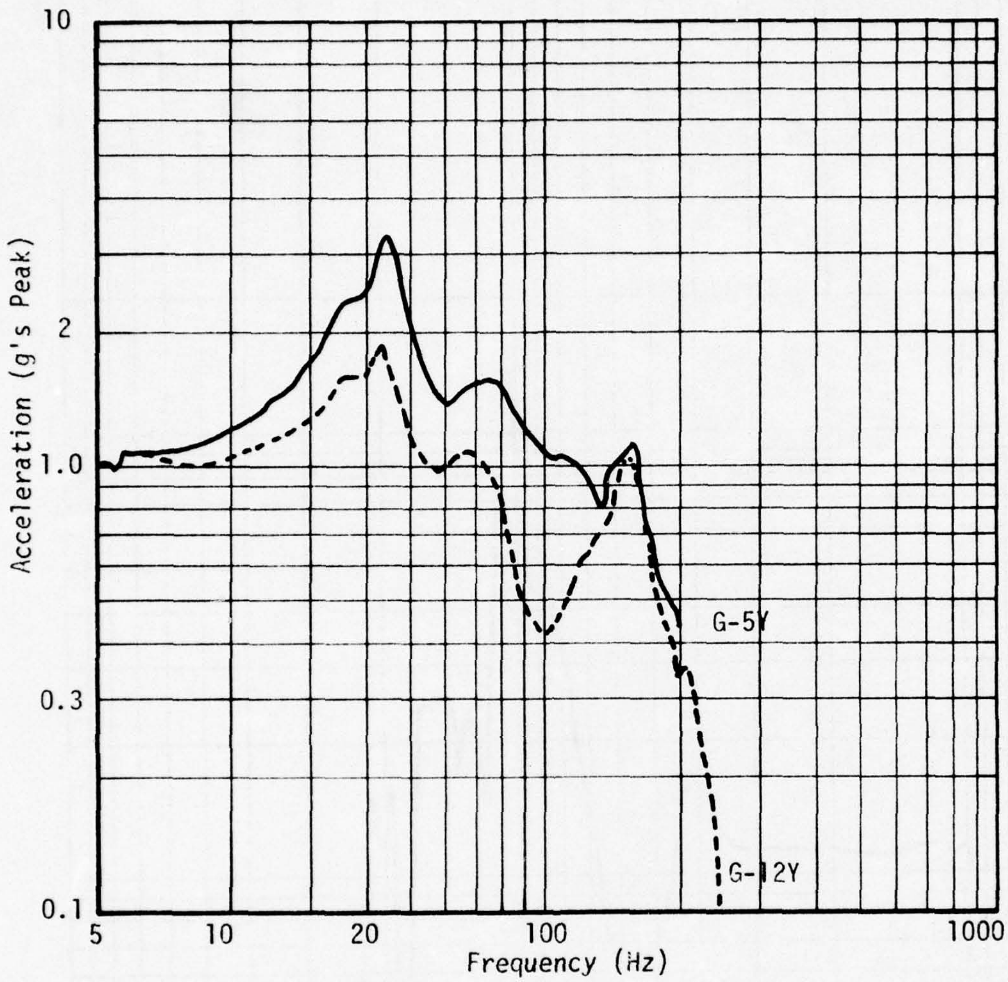


FIGURE I-10. RUN NO. 004, 10 TO 300 HZ SWEEP

AT 1G CONSTANT ACCELERATION

(ACCELEROMETER NOS. G-5Y AND G-12Y)

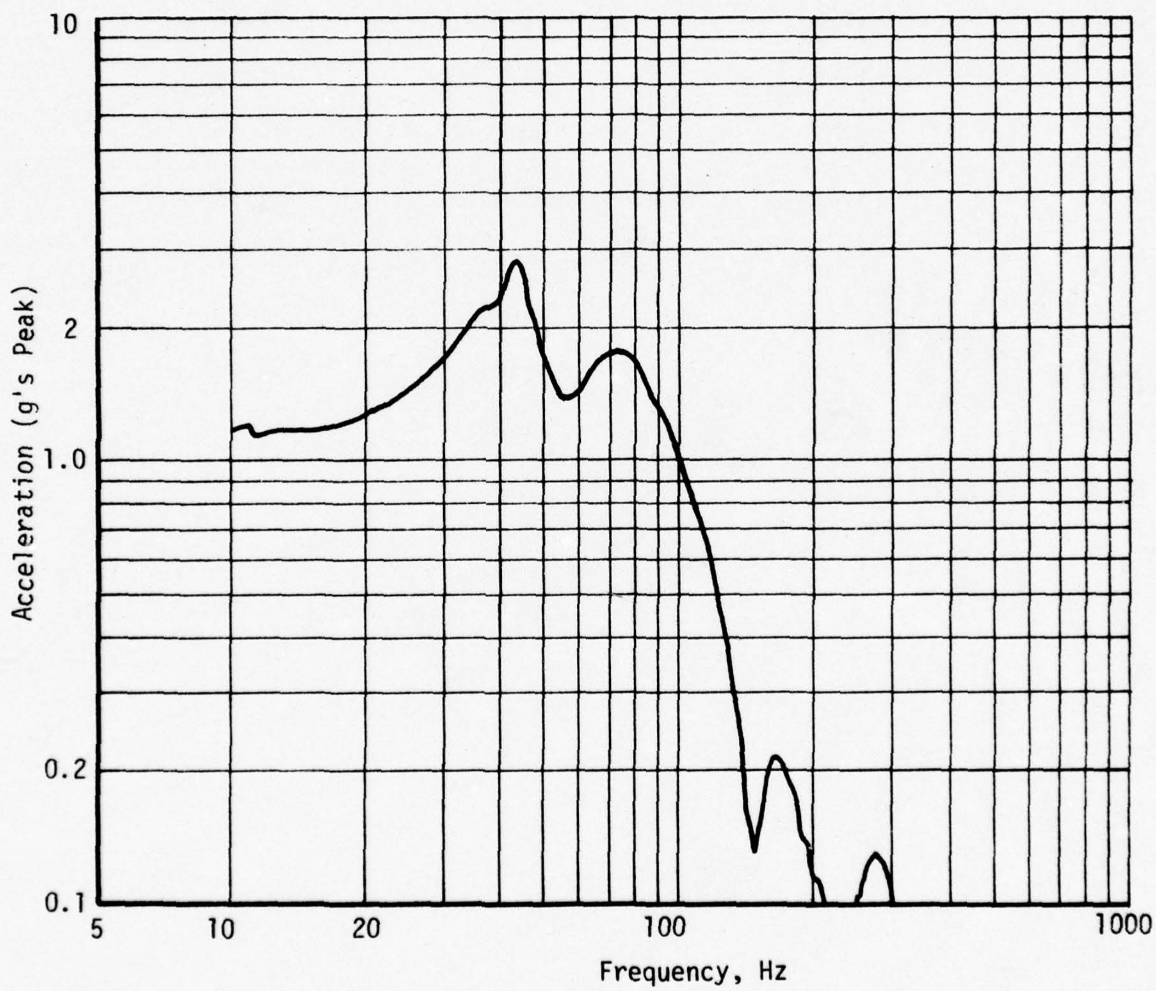


FIGURE I-11. RUN NO. 004 - 10 TO 300 HZ SWEEP AT 1 G
CONSTANT ACCELERATION (ACCEL. NO. G-14 G)

TABLE I-1

VIBRATION STRESSES MOTOR NO. 1 AT RESONANCE 45.1 Hz:
2 g ACCELERATION LEVEL
LONGITUDINAL VIBRATION TEST

Gage No.	Stress PK-PK	Gage No.	Stress PK-PK
S-1	1.92	N1-2	5.7
S-3	1.76	N2-1	7.58
S-4	1.65	N5-1	1.36
S-5	1.07	N6-1	2.75
S-6	1.82	N7-1	4.63
S-7	1.40	N9-1	1.28
S-8	.95	N10-1	1.93
S-9	3.33	N11-1	15.92
S-10	4.09	N15-2	--
S-13	6.21		

APPENDIX J

SUMMARY OF THE HANDLING AND TRANSPORTATION TESTS

HANDLING AND TRANSPORTATION TESTS

A. HANDLING TESTS

The handling tests were conducted to subject the motor to all of the required handling conditions: lifting, tip over and rolling. During each of the tests performed in the Manufacturing Area, the propellant stress/strain gages were monitored continuously on an oscillograph.

The primary objective of this test was to simulate the conditions to which a typical motor was subjected during processing operations and to verify that the stresses produced during handling are of a low magnitude and, therefore, relatively unimportant to overall motor design.

1. Description and Test Procedures For Handling Tests

a. Lifting Operations

(1) With Motor No. 1 in a horizontal position on a trailer, transfer the motor to an area accessible to an overhead hoist (Figure J-1).

(2) Zero and balance all instrument channels and record zero reading.

(3) Turn on recorders prior to the lifting operation; monitor and record all channels continuously until end of the operation.

b. Rolling Operation

(1) Transfer Motor No. 1 to the roller fixture permanently attached to the building.

(2) Zero and balance all channels and record zero readings.

(3) Turn on recorders prior to the start of the rolling operation; monitor and record all channels continuously until five complete revolutions have been made and the test is stopped.

c. Tipping Operations

(1) Transfer the motor from the roller fixture to the T-416438 transport trailer shown in Figure J-2.

(2) Move the motor to area accessible to an overhead hoist and attach hoist to yoke on the aft-end trailer.

(3) Zero and balance all instrument channels and record zero readings.

(4) Turn on recorder prior to tipping operation. Monitor and record all channels continuously until end of tipping operation with the longitudinal axis of the motor elevated to an angle of 90°.

2. Summary of Handling Tests

The rolling test was conducted in the Manufacturing area using a Polaris rolling fixture. The test involved three complete rolling cycles of the motor. Twenty-four channels of gages were recorded dynamically onto two oscillographs. The horizontal lifting test was conducted and monitored continuously with the 24 channels of dynamic recording. The test was repeated in slow motion to enable monitoring the internal LVDT's and D.C. pots which are recorded on a static recording system. The tipping and vertical lifting were conducted and monitored continuously with the dynamic recording system. That operation was repeated in slow motion in order to record the channels on the static recording system. This was done by stopping at every 10 degree increment to 90 degrees or to the vertical position. At the vertical position, the motor was lifted vertically and all channels were recorded.

The data obtained from the roll tests performed as a part of the handling tests on the motor are summarized in Figures 45 and 46 of Volume I. The stress changes appear to be reasonable in view of the calculated lateral stresses given in Appendix P. The greatest shear stress was obtained from gage SH-5 (Figure 45 of Volume I). This was unusual since gage SH-5 was positioned in a fore and aft direction and should not respond significantly to the roll test. Both shear gages SH-12 and SH-14 which were rotated through 90° so as to measure these types of stress were inoperative during the roll test. Gage SH-12 failed during the test and gage SH-14 was erratic.

With the exception of SH-5, a typical shear stress variation during a roll test was about 0.3 psi from peak to peak. The normal stress gages show larger outputs as would be expected. From these gages it appeared that roll stresses about 2.5 to 3.0 psi peak-to-peak may be anticipated. The stresses due to handling must be added to the existing thermal and gravitational stresses.

The results of the vertical tilt test from a horizontal position to a vertical position are given in Table J-1. All of the stress differences were small except for gage N11-1 which is at the aft equator. Without a stress analysis it is hard to make a good assessment. But, these stresses are less than was anticipated.

B. TRANSPORTATION TESTS

The primary objective of this test was to simulate the conditions to which the stage II Minuteman motor was subjected to during transportation and to monitor the stresses produced during transportation.

The first test involved the transfer from the storage vehicle and consisted of lifting and placing the motor in a horizontal position from the cart (T-103457) shown in Figure J-1 to the transporter shown in Figure J-2. This test is very similar to the lifting series of the handling test. The second half of the transportation test consisted of the transfer of the motor from the transporter (TPC Harness) to a utility van. The motor was lifted horizontally with forward end facing the van and placed on transfer rails on the loading platform. It was then towed along the tracks of the platform to the tracks leading into the van with a motor driven winch. The recorders were turned on prior to lifting in both cases and all channels which were selected to be monitored, were recorded continuously until the end of operation.

1. Description of Test Vehicles

a. Transfer From Storage to Transporter

A Boeing Company TBC operational harness and an ASPC semi-trailer were used for this test of Motor No. 1.

b. Transfer Motor From Transporter to Transporter

A semi-trailer and a utility van were used in this test where Motor No. 1 was transferred from its original position in the semi-trailer to the utility van.

2. Test Procedures

a. Transfer From Storage to Transporter

During this operation the stresses of the propellant grain were monitored. The test procedures were as follows:

(1) Hookup and connect instrumentation.

(2) Zero and balance all channels. Record all zero readings.

(3) Monitor and record all channels continuously until end of operation.

b. Transfer of Motor From Transporter to Transporter

During this operation the stresses of the propellant grain were monitored. The test procedures were as follows:

(1) Safety: The motor must be grounded to van at all times after installation.

(2) Safety: Do not detach winch cable or brake cable until motor is tied down.

(3) Ensure van brakes are set. Install two jacks beneath the rear end of the van, one jack under each van rail.

(4) Clean interior of van thoroughly.

(5) Remove the aft spreader track from the aft end of van.

(6) Attach the transfer rails and "A" frame assembly to trailer rails, then adjust jacks under van and adjust "A" frame as required to level. Level in both the longitudinal and transverse directions.

(7) Instrumentation, monitoring schdule, and data acquisition system were identical to the storage-to-transporter test.

(8) Position the tow cable through the pully in van and secure to the carriage forward end. Secure the other cable to the aft end and take up slack in both cables.

(9) Zero and balance all instrumentation channels. Record zero readings.

(10) Using the winch, tow the motor into the van and position it over forward tie down area.

(11) Monitor and record all channels continuously until end of operation.

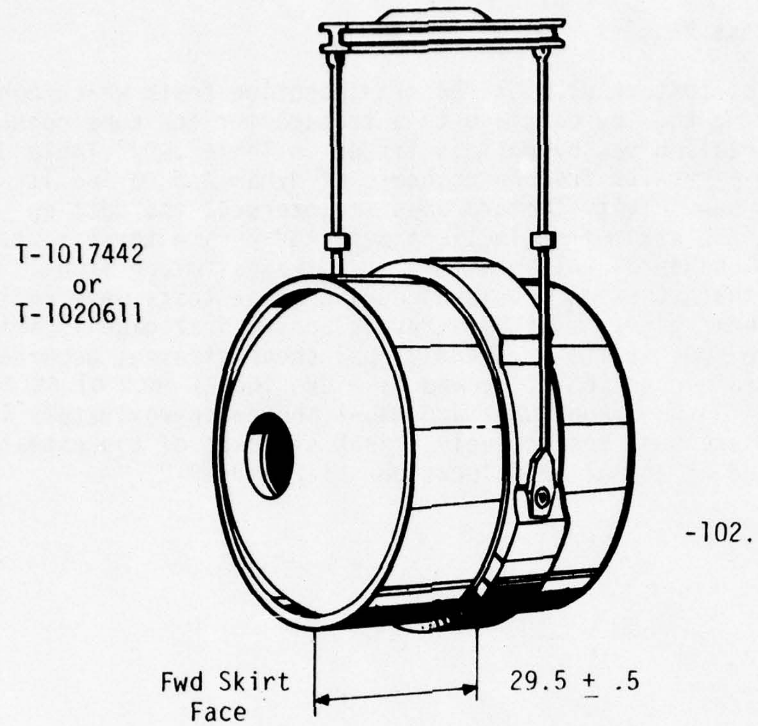
(12) Stop recorder, rezero instrumentation.

(13) Position motor installed on its trailer adjacent to transfer rails and accessible to overhead hoist; then using overhead hoist and T-1021847 spanner beam with four 1/2" dia x 40-1/2" long cables and 3/4" shackles connected to carriage hoist points, lift motor clear of its trailer and position on the transfer rails with forward end of motor facing toward van. Turn recorders on prior to lifting and monitor all channels continuously until end of operation.

NOTE: ENSURE BOTH CABLES ARE TAUT DURING MOTOR TRANSFER

3. Test Results

The test results of the transporation tests which consist of transferring the TBC carriage to a transporter and subsequently to the MM transportation van by rail is listed in Table J-2. Table J-2 summarizes the test results from 24 channels of dynamic data and it lists the voltage sensitivity factors used to interpret the data on the oscillograms, the maximum deflections detected during these tests, and the resulting change of voltages (mv) and strains (micro inch). Results indicate that stresses developed during these tests were negligible. For the shear gages, maximum stresses occurred at gage locations S-9 and S-10 where approximately .2 and .1 psi shear stresses occurred, respectively. Strain gage SCAT-2 showed 41 micro inches/inch of strain in the forward head. Normal gages N8-1 and N10-1 showed approximately 1.5 and 1.0 psi peak stresses, respectively. Peak stresses of approximately 5 to 7 psi occurred at normal gage locations N1-2 and N4-2.



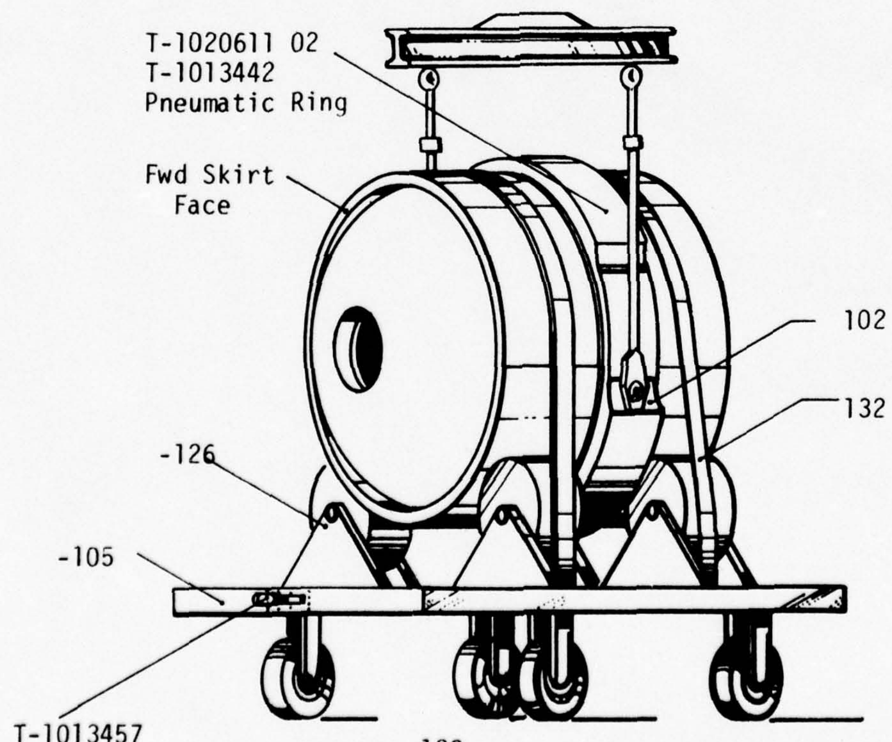


FIGURE J-1. LIFTING OPERATIONS

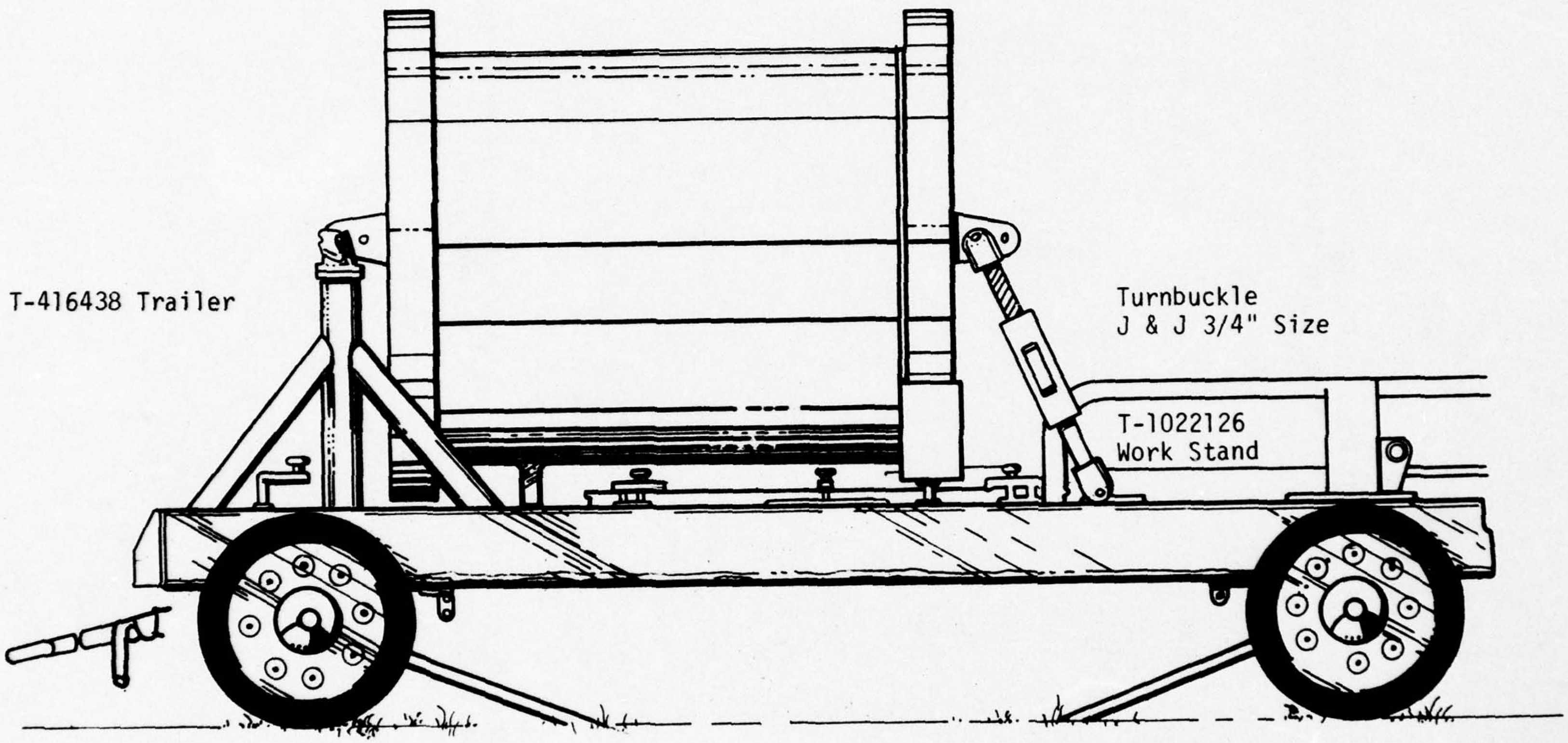


FIGURE J-2. T-416438 TRANSPORT TRAILER FOR HANDLING AND TRANSPORTATION TESTS

TABLE J-I

CHANGE IN GAGE OUTPUTS IN PSI FOR TILTING MOTOR AXIS FROM THE HORIZONTAL TO THE VERTICAL POSITION

Gage No.	Stress Change, psi
SH-4	+0.67
SH-8	+0.31
SH-3	+0.70
SH-7	+0.38
SH-2	Failed
SH-6	+0.18
SH-1	-0.35
SH-5	+0.56
SH-9	-0.69
SH-11	+0.88
SH-12 (90°)	+0.32
SH-14 (90°)	-0.60
SH-10	+0.75
N11-1	+1.67

Note the different stress changes between the pairs of shear gages nominally at similar locations in the grain.

TABLE J-2

SUMMARY OF RESULTS FROM TRANSPORTATION TESTS

Normal Gages	Sensitivity Factors Used on Oscillographs (Inches/mv except where noted)	Max. Deflections From Start of Test (Inches)	Voltage Changes (Strain Changes Noted) (mv)
N1-2	.73	1.5	2.05
N4-2	.65	2.4	3.7
N5-2	.70	.2	.28
N6-1	.60	.1	.17
N7-1	.34	.1	.30
N8-1	.60	.8	1.33
N9-1	.57	.28	.50
N10-1	.34	.30	.86
N11-1	.45	.20	.44
N15-2	-	-	-
Shear Gages			
S-1	.25	.025	.10
S-3	.45	.075	.12
S-4	.25	.025	.10
S-5	.75	.050	.065
S-6	.55	.050	.09
S-7	.55	.050	.09
S-8	.67	.050	.08
S-9	.55	.300	.54
S-10	.35	.100	.29
S-11	.45	-	-
S-12	.76	-	.13
S-14	.51	0	0
Strain Gages			
SCAT-1	.48 in/375μ "/"	.025	15 micro inch/inch
SCAT-2	.45 in/375μ "/"	.050	41 micro inch/inch

APPENDIX K

SUMMARY OF TEST MEASUREMENTS FOR MOTOR NO. 2

SUMMARY LOG OF TEST MEASUREMENTS FOR MOTOR NO. 2

A. INSTRUMENTATION

The instrumentation of Motor No. 2 was similar to that of Motor No. 1 except that additional stress gages were installed in the aft dome to measure stresses at locations considered to be critical in motor firings.

B. TEST SCHEDULE

The calibration and test schedule for Motor No. 2 is shown in Figure K-1.

C. TESTS AND CALIBRATIONS

The stress gages installed in the motor were calibrated before and after the propellant grain was cast. These calibrations consisted of pressurizing the chamber (precast) or motor (cast) with gaseous nitrogen to 50 psig in incremental steps of 10 psig while recording the stress gage outputs. The precast pressure calibration curves for the normal gages at ambient temperature are shown in Figure K-2. The post-cast pressure calibration curves for the 450 psig and 150 psig normal stress gages and shear gages are shown in Figures K-3, K-4 and K-5, respectively. The measured pressure (stresses) as a function of applied pressure for some of the normal gages are shown in Figures K-6 and K-7. Additionally, a pressure and thermal calibration for the installed gages were performed by pressurizing the chamber (precast) to 15 psig in steps of 5 psig at 30°F, 77°F and 110°F. This pressure exercise was conducted when the gages were initially installed to verify proper polarity, proper hookup and to provide a baseline calibration for future data analyses. The results of all the above tests were indicated in Table K-1, which shows the test data presented in terms of zero stress conditions and gage sensitivity (mv/psi) at temperatures of 30°F, 77°F and 110°F. The checkout data (zero stress-precast) for Motor No. 2 at 77°F is shown in Table K-2.

After gage installation, checkout and calibration, the chamber was processed through the Manufacturing Operations. Test measurements were made during the cast, cure and cooldown operations. The cure and cooldown stresses are shown in Figures K-8 through K-11. Stresses produced during core removal were monitored. Approximately 1500 lbs of load was required to remove the core. Upon completion of the casting and trimming operations, and after achieving temperature equilibrium, the gages were then pressure calibrated at temperatures of 33, 77, and 130°F. These calibration results were also included in Table K-1.

With the emphasis placed on Motor No. 1, only a few data were reduced from the measurements made on Motor No. 2. The data in Table K-3 give a comparison of the thermal stresses at the end of cure and after cooldown between the two motors. Some differences are noted; particularly in the shear stress measurements.

The motor was subsequently X-rayed on 17 July 1973 in conformance with AGC-32188. The results of the radiographic inspection report were similar to most third stage Minuteman motors cast and are shown in Table K-4. Motor No. 2 is presently being stored and aged in Building No. 131 in the Manufacturing Area at 80 ± 20°F. The purpose of this storage was to simulate field environments to which the third stage Minuteman motors are subjected. Final disposition of Motor No. 2 will be determined by AFRPL and ASPC.

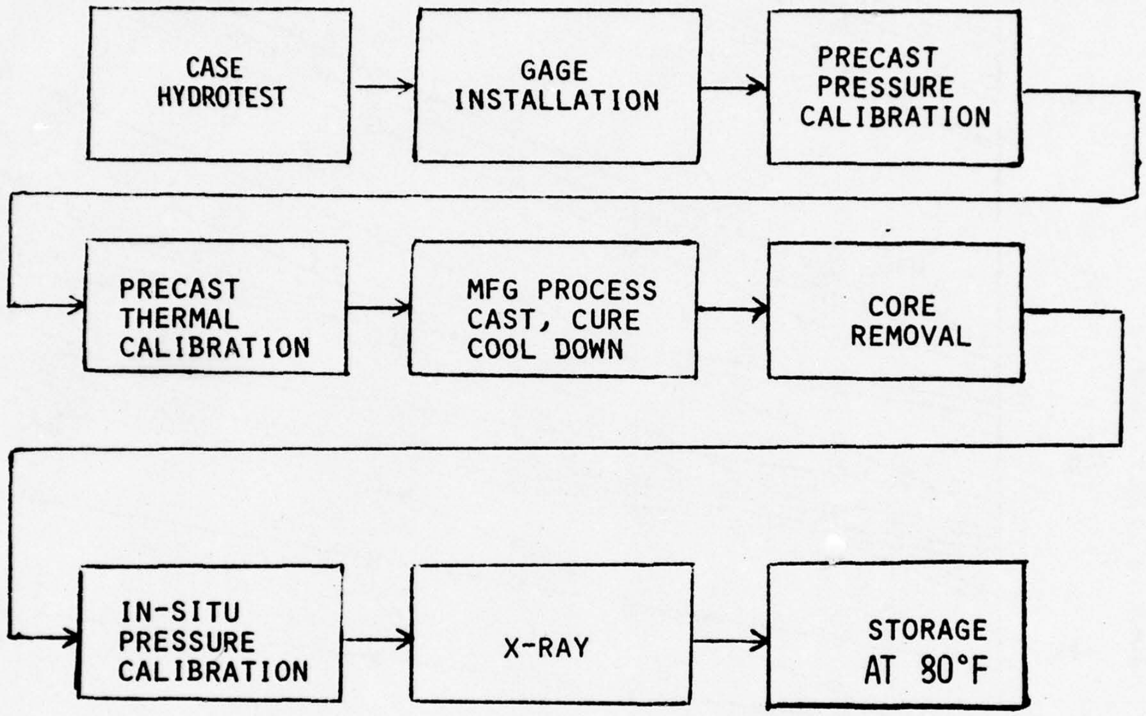


FIGURE K-1. CALIBRATE & TEST FLOW DIAGRAM FOR MOTOR NO. 2

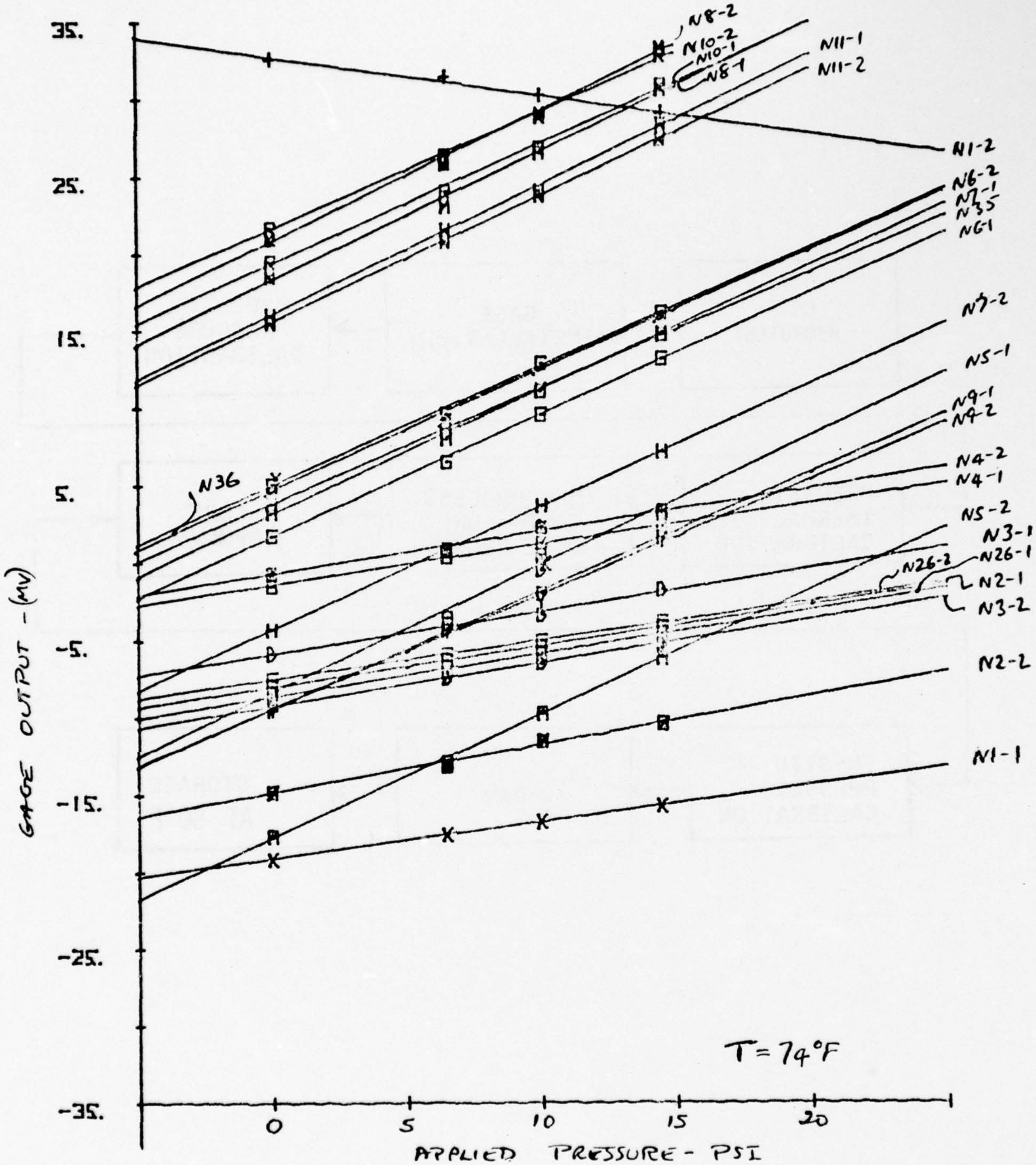


Figure K-2. Pre-Casting Pressure Calibrations ASPC Motor# 2

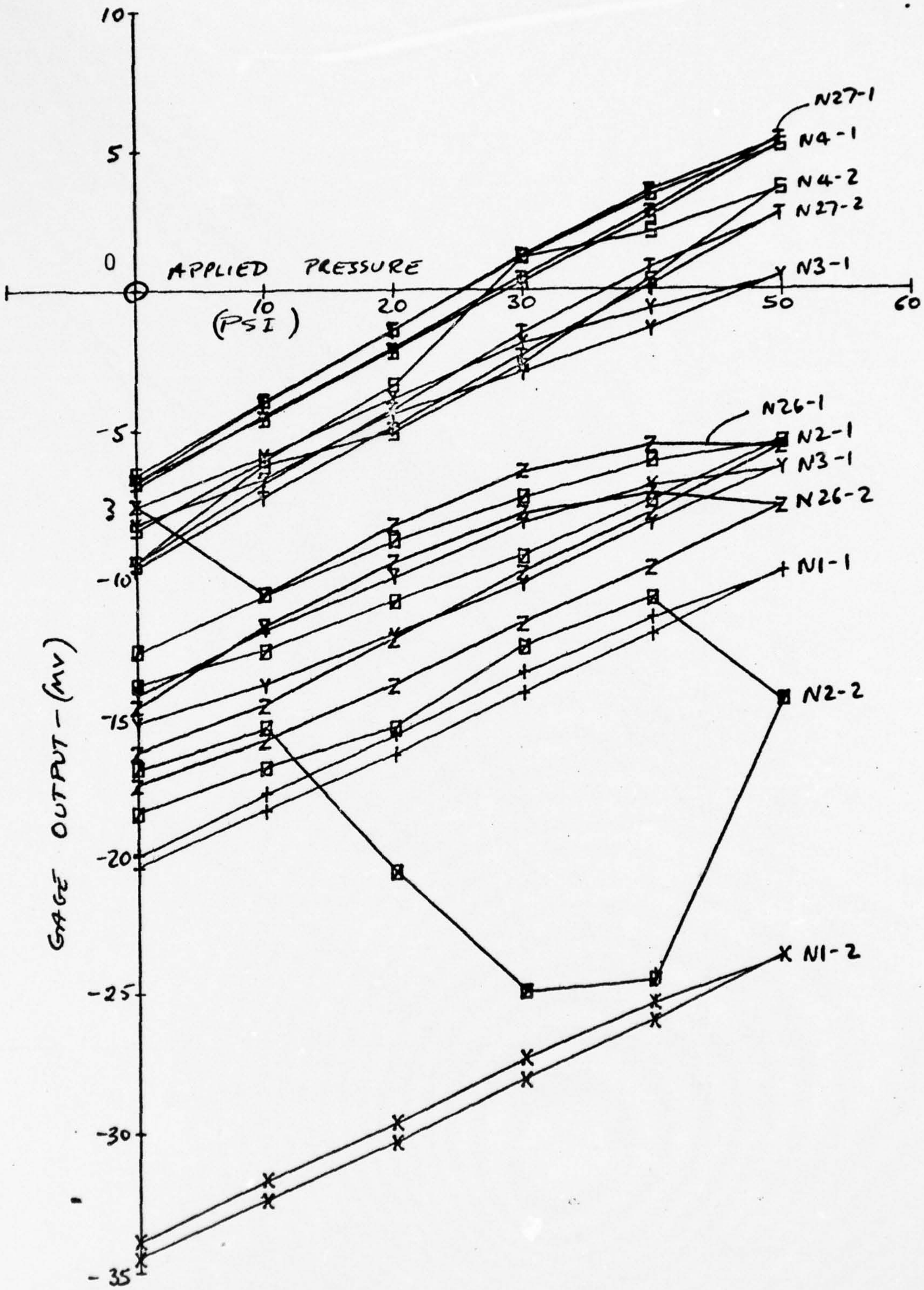


Figure K-3. Post Casting Pressure Test Data ASPC Motor # 2
450 psi Normal Stress Gages

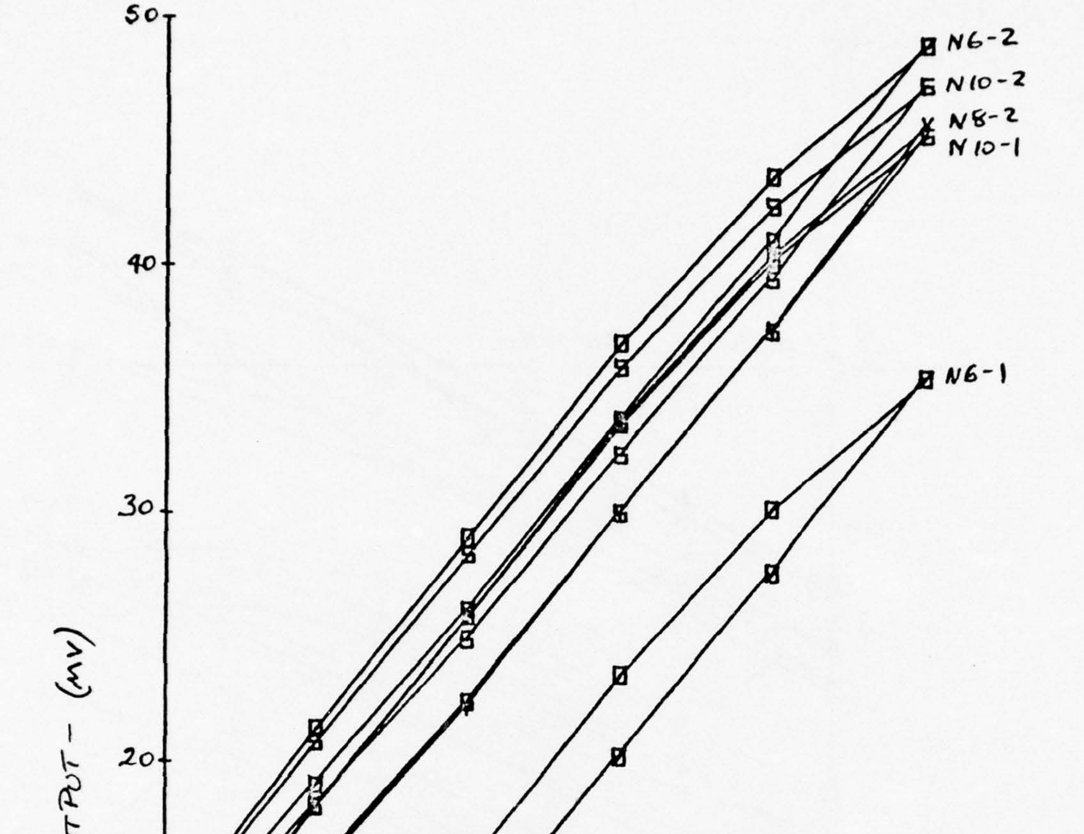


Figure K-4. Post Casting Pressure Test Data 150 psi Gages in ASPC Motor #2

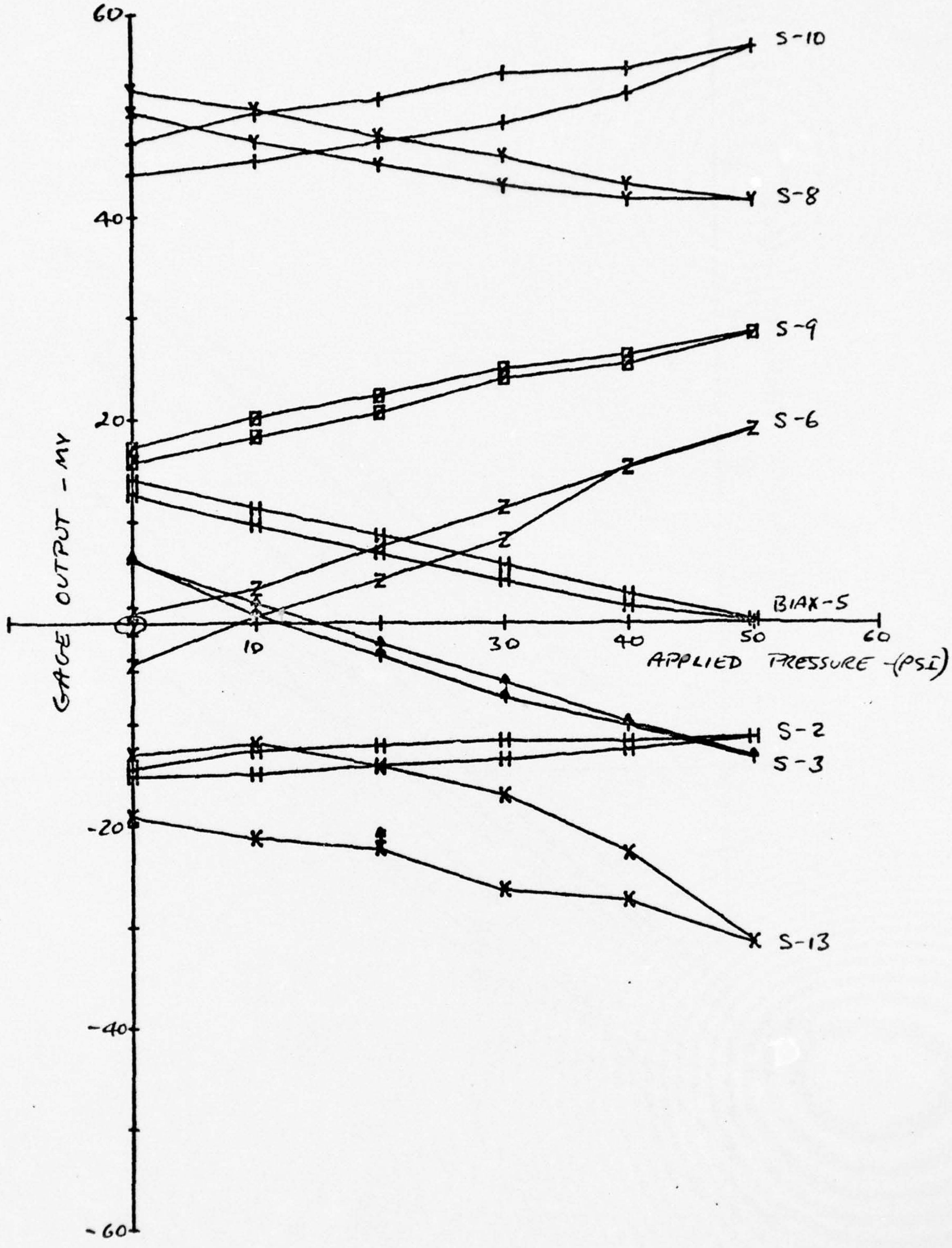


Figure K-5. Post Casting Pressure Test Data from Shear Gages in ASPC Motor # 2

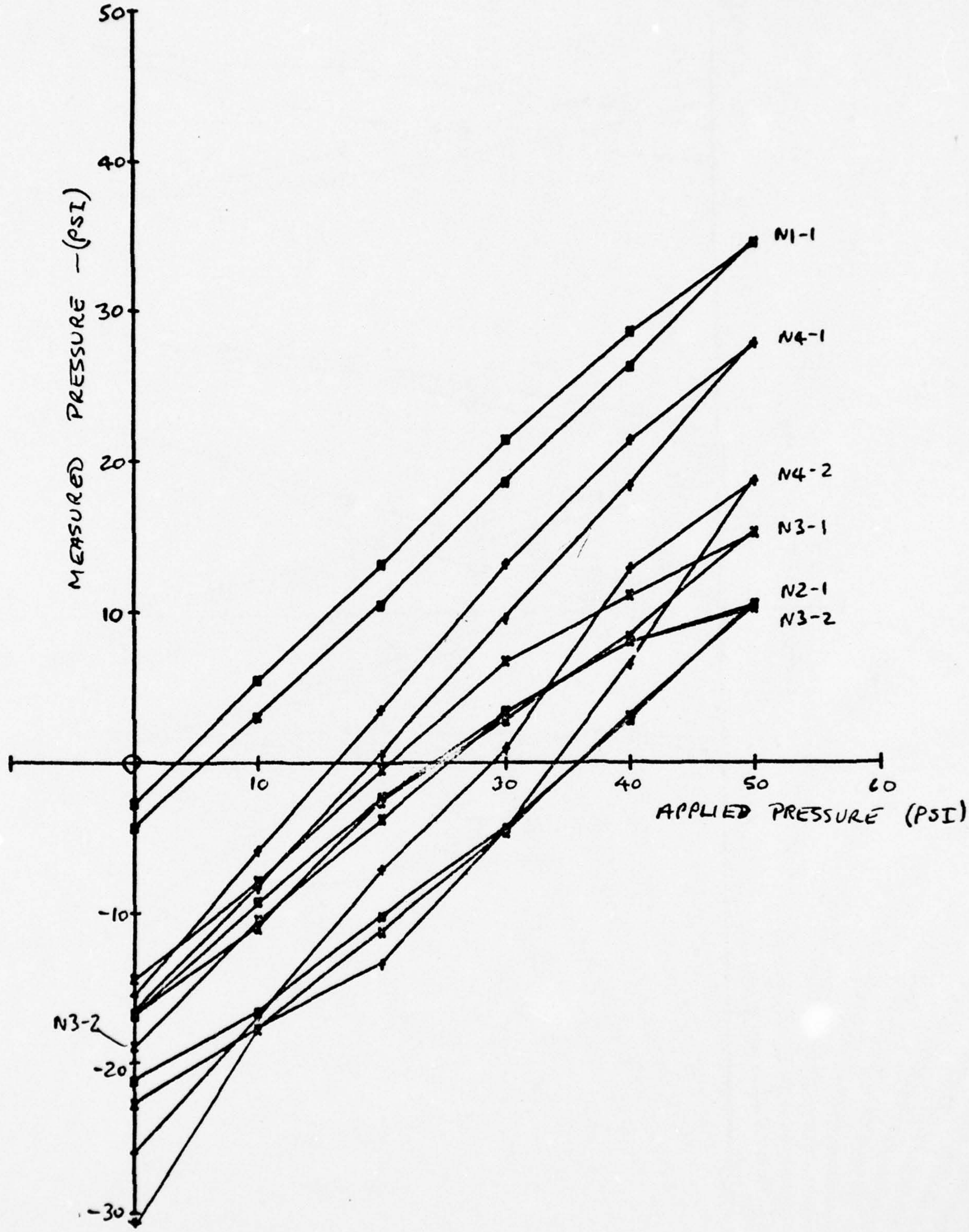


Figure K-6. Post Casting Pressure Stresses from 450 psi Gages in ASPC Motor # 2

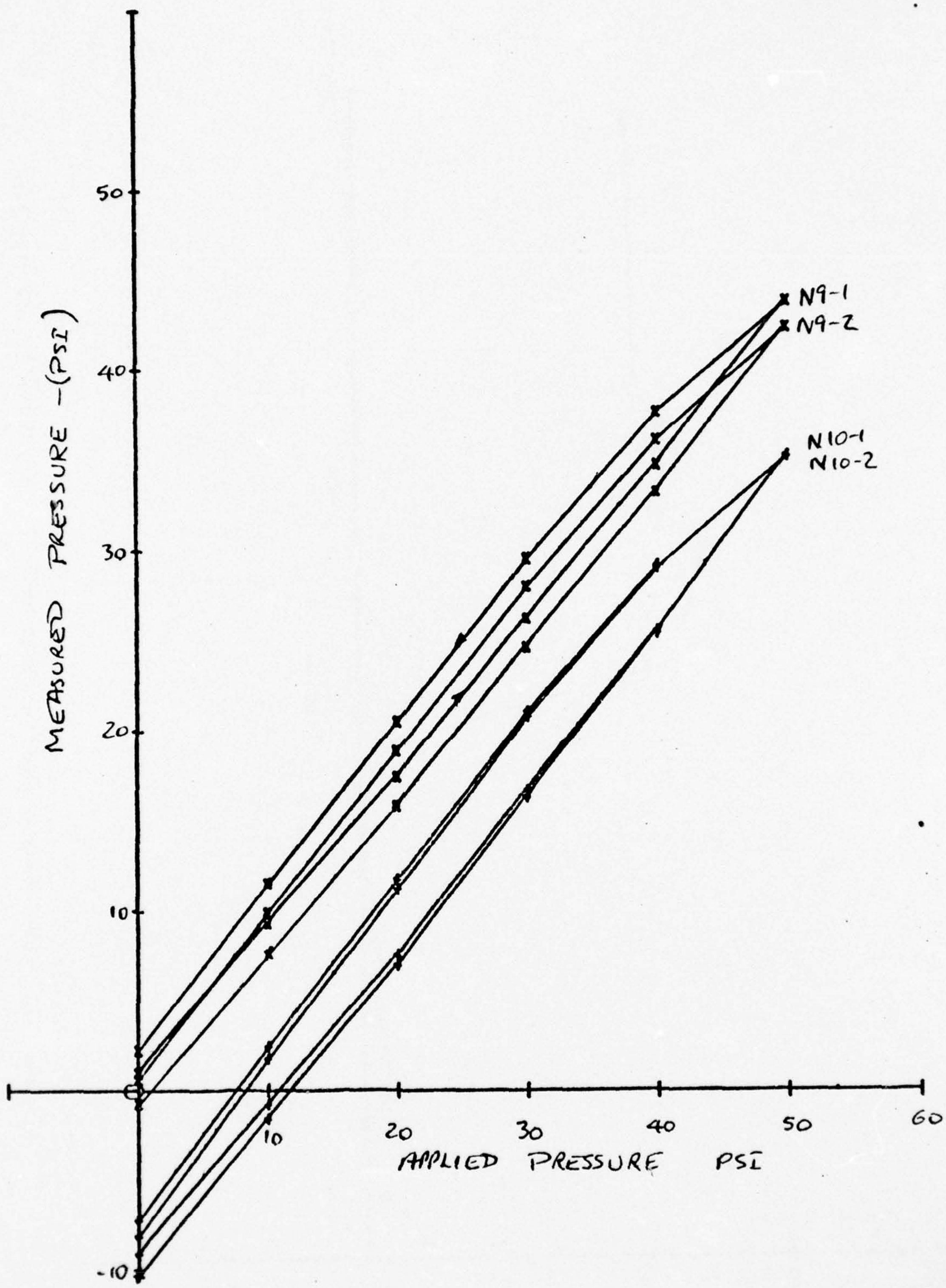


Figure K-7. Post Casting Pressure Stresses from 150 psi Gages in ASPC Motor #2

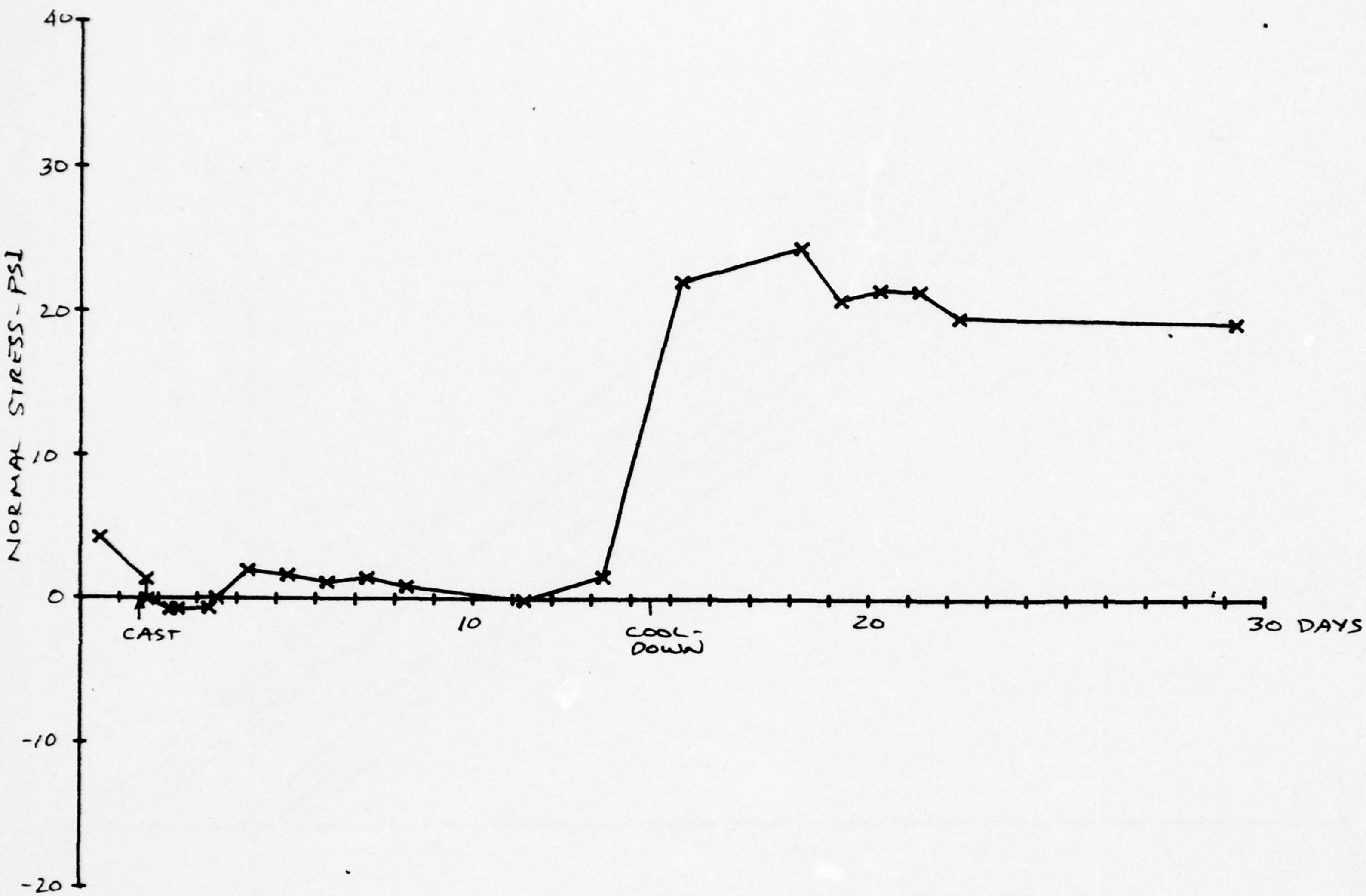


Figure K-8. Cure and Cooldown Stresses on Full Scale Motor No. 2; Gage N2-1

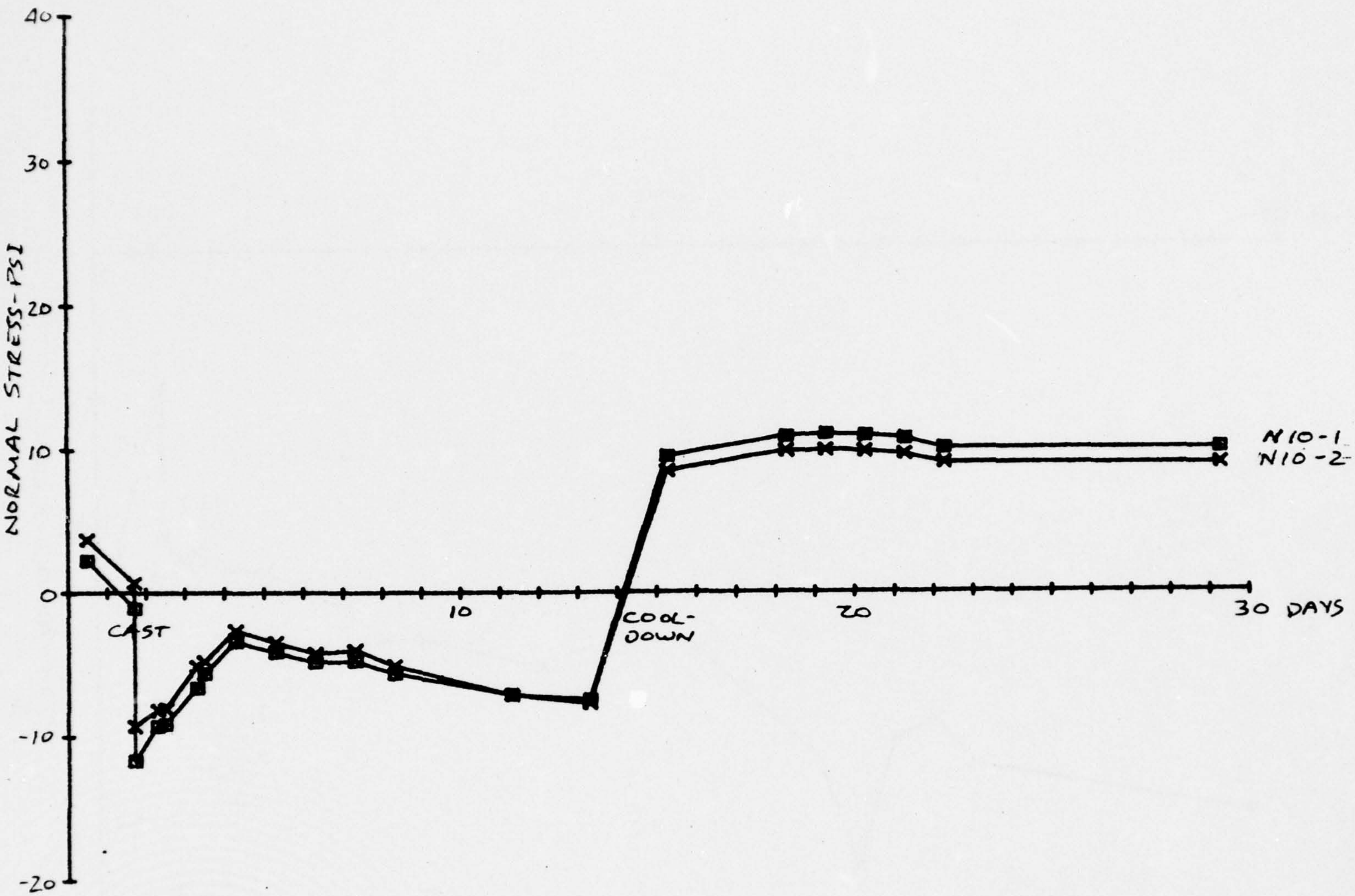


Figure K-9. Cure and Cooldown Stresses on Full Scale Motor No. 2; Gages N10-1 and N10-2

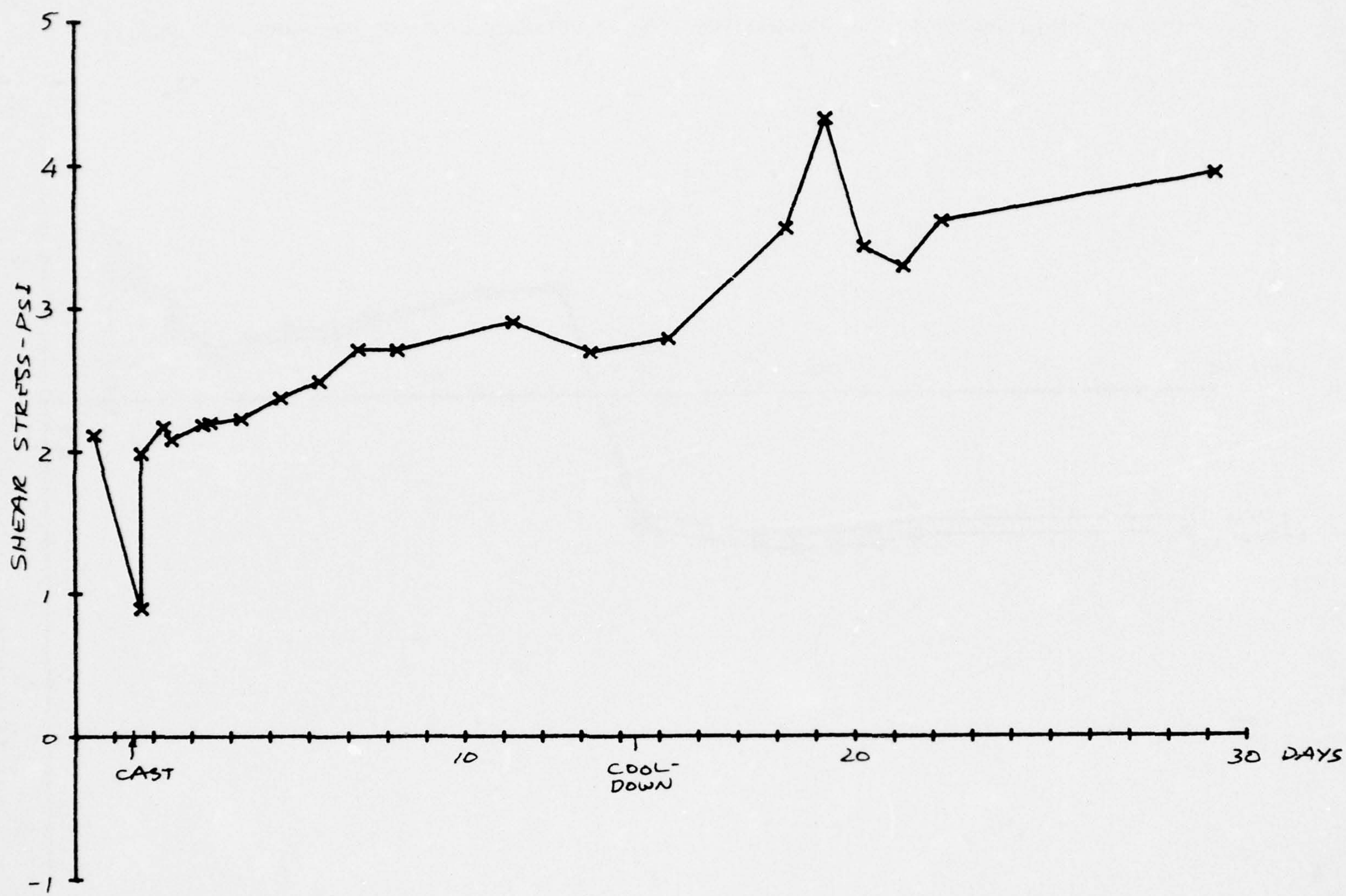


Figure K-10. Cure and Cooldown Stresses on Full Scale Motor No. 2; Gage S-10

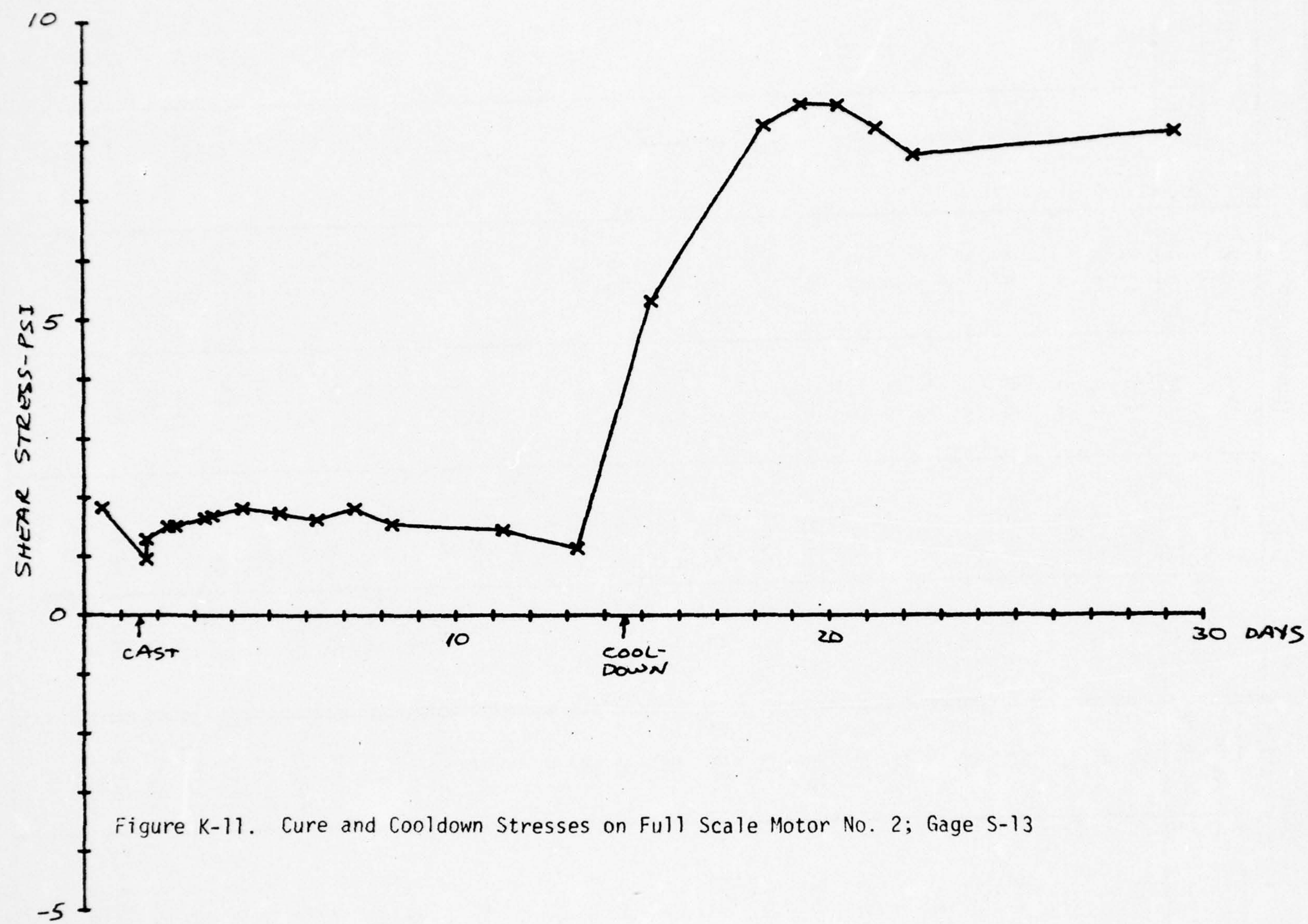


Figure K-11. Cure and Cooldown Stresses on Full Scale Motor No. 2; Gage S-13

TABLE K-1

FULL SCALE MOTOR NO. 2 GAGE DATA

GAGE IDENTIFICATION		TEMPERATURE					
		33°F	30°F	77°F	74°F	130°F	110°F
Motor No.	KI or HL&A No.	SENSITIVITY MV/PSI	ZERO RDG.	SENSITIVITY MV/PSI	ZERO RDG.	SENSITIVITY MV/PSI	ZERO RDG
S-1	30	4.35	+2.1 mv	4.6	+1.8	4.8	+2.7
S2	26	4.0	-7.3	4.8	+1.8	4.6	+6.7
S3	27	3.8	-1.4	4.1	-1.8	3.8	-2.0
S-4	42	3.05	-3.2	3.65	+4.5	(+144) 3.7	+11.1
S-5	32	3.6	+0.2	3.6	+3.5	3.5	+5.2
S-6	29	3.6	+8.3	3.85	+1.3	3.75	-4.3
S-7	31	4.0	-6.5	3.9	0.0	3.76	-1.2
S-8	33	2.0	+10.0	2.0	+6.5	(144°F) 2.0	+4.5
S-9	S-B	*	-0.5	*	0.0	*	-1.8
S-10	34	2.6	+42.0	2.4	+37.5	(144°F) 2.2	+35.0
S-11	13	3.2	+5.8	3.0	-0.5	3.5	-3.5
S-12	35	2.6	+4.0	2.3	+1.2	(144°F) 2.45	+1.4
S-13	25	2.8	-2.4	3.1	-2.6	3.2	-1.7
S-14	36	2.1	-0.7	1.9	-1.0	1.6	-1.8
Shear A	S-A	*	-3.7	*	-1.5	*	-0.4
Shear C	S-C	*	+0.2	*	0.0	*	-1.0
Shear D	S-D	*	+0.1	*	-1.0	*	-0.3
N1-1	450/3-1	.268	-19.2	.269	-19.2	.271	-20.2
N1-2	450/3-2	.271		.272		.272	
N2-1	450/11-1	.269	-12.0	.271	-8.6	.269	-7.2
N2-2	450/11-2	.272	-14.9	.274	-14.8	.272	-15.3
N3-1	450/4-1	.275	-10.2	.274	-4.0	.272	-4.3
N4-1	450/22-1	.270	-3.0	.270	-2.5	.270	-1.3
N4-2	450/22-2	.272	-2.1	.272	-1.6	.274	-0.3
N5-1	150/21-1	.823	-7.5	.821	-8.4	.818	-8.6
N5-2	150/21-2	.820	-18.4	.821	-17.7	.826	-17.8
N6-1	150/6-1	.811	+2.0	.807	-1.7	.807	-0.9
N6-2	150/6-2	.812	+5.9	.811	+5.1	.811	+3.4

*Viscoelastic Calibration. See Curves

TABLE K-1

FULL SCALE MOTOR NO. 2 GAGE DATA (Cont)

GAGE IDENTIFICATION		TEMPERATURE					
		33°F	30°F	77°F	74°F	130°F	110°F
Motor No.	KI or HL&A No	SENSITIVITY MV/PSI	ZERO RDG.	SENSITIVITY MV/PSI	ZERO RDG.	SENSITIVITY MV/PSI	ZERO RDG
N7-1	150/29-1	.816	+3.7	.814	+3.2	.816	+4.0
N7-2	150/29-2	.820	-5.1	.816	-4.3	.818	-3.8
N8-1	150/2-1	.825	+18.7	.819	+18.5	.813	+17.3
N8-2	150/3-2	.818	+20.3	.818	+21.0	.812	+2.07
N9-1	150/28-1	.811	-8.0	.813	-10.5	.811	-11.5
N9-2	150/28-2	.801	-9.5	.806	-10.7	.807	-11.2
N10-1	450/7-1	.270	+18.0	.271	+16.7	.268	+18.0
N10-2	450/7-2	.272	+20.0	.271	+18.7	.274	+20.5
N11-1	150/4-1	.841	+16.8	.839	+15.2	.841	+14.8
N11-2	150/4-2	.806	+15.3	.806	+15.5	.805	+15.2
N26-1	450/26-1	(-75) .268	-10.9	.269	-8.0	(+180) .270	-6.3
N26-2	450/26-2	(-75) .270	-10.7	.270	-7.5	(+180) .270	-6.3
N27-1	450/27-1	(-75) .270	-0.7	.266	+2.8	(+180) .267	+4.3
N27-2	450/27-2	(-75) .268	+2.6	.266	-1.7	(+180) .270	-1.8
BI-7SH	3D5	*	+13.0		+10.1		+7.6
BI-5SH	3D5	*	+7.0		+20.7		+25.7
6A-D	3D5	*	-12.2		+11.0		+23.0
6B-D	3D5	*	+5.1		+18/7		+25.0
5A-D	3D5	*	+23.8		+28.7		+30.6
7A-D	3D5	*	-3.8		+0.4		+1.6
2+	3D6-4	*	+7.0		-1.8		-11.8
2-	3D6-3	*	-10.3		-20.5		-13.0
3+	3D6-6	*	-9.0		-19.0		-29.0
3-	3D6-5	*	-13.8		-27.6		-37.5
1+	3D6-2	*	-13.5		-18.0		-24.5
1-	3D6-1	*	+16.3		+11.3		+3.0
N35	150/35-1	(0°F) .761		.759		(150°F) .762	
N36	150/36-1	(0°F) .792		.804		(150°F) .812	

*Viscoelastic Calibration. See Curves

TABLE K-2

MOTOR NO. 2 CHECKOUT DATA (ZERO STRESS - PRECAST)
(NORMAL STRESS GAGES)

Normal Gages	S/N	Output (MV) Reading at 77°F
N1-1	3	-18.7
N1-2	3	34
N2-1	11	- 9.6
N2-2	11	-14.6
N3-1	4	- 4.7
N3-2	4	- 9.4
N4-1	22	- 2.4
N4-2	22	- 1.4
N5-1	21	- 8.2
N5-2	21	-17.7
N6-1	6	1.8
N6-2	6	5.1
N7-1	29	3.2
N7-2	29	- 4.8
N8-1	3	18.3
N8-2	3	20.7
N9-1	28	-10
N9-2	28	-10.7
N10-1	7	+17
N10-2	7	+19.4
N11-1	4	+16.0
N-11-2	4	+16.0

TABLE K-3

THERMAL STRESS COMPARISON AT END OF CURE AND AFTER COOLDOWN: FULL SCALE THIRD STAGE MINUTEMAN MOTORS NO. 1 AND 2

	STRESSES IN FS # 1			STRESSES IN FS # 2		
GAGE #	END OF CURE	AT 70°F	STRESS CHANGE	END OF CURE	AT 70°F	STRESS CHANGE
N-10	-8 psi	9 psi	17 psi	-8 psi	10 psi	18 psi
N-2/1	0.0	19	19	1	21	20
SH-10	0.3	-3.3	-3.6	2.7	3.4	0.7
SH-13	0.5	-9.0	-9.5	1.5	8.5	7.0

TABLE K-4

RADIOGRAPHIC INSPECTION MINUTEMAN MOTOR, STAGE III

Motor No. 002 , TC-30113 Date: July 17, 1973

CASE/INSULATION SEPARATION		
Forward Zone	In^2	18
Cylindrical Zone	In^2	None
Aft Zone	In^2	None
PROPELLANT/INSULATION SEPARATION		
Forward Zone	In^2	None
Cylindrical Zone	In^2	None
Aft Zone	In^2	None
BOOT/INSULATION JOINT		
Forward: Minimum Bond	Satisfactory	
Aft : Minimum Bond	N/A	
PROPELLANT DEFECTS		
Cracks - None		
Voids - None		
Other - None		

REMARKS:

1. Motor contains a moderate amount of liner ridging noted in the aft knuckle area.
2. Motor contains case/insul. separation adjacent to the igniter boss. This separation ranges from 0.25" to 1.9" long and is noted at six (6) different tangent points. Total of 18 $In.^2$.
3. Motor contains numerous sensoring devices and wires attached to the motor at different places.

C.F. Broman
Radiographer
Department 5254

Motor conforms to AGC 32188F

AD-A032 637 AEROJET SOLID PROPULSION CO SACRAMENTO CALIF F/G 21/9.2
FLEXIBLE CASE-GRAIN INTERACTION IN BALLISTIC WEAPON SYSTEMS. VO--ETC(U)
OCT 76 K W BILLS, S W JANG, H LEEMING F04611-72-C-0055
UNCLASSIFIED ASPC-1953-81-F-VOL-3 AFRPL-TR-76-57-VOL-3 NL

4 OF 4
AD
A032637

END
DATE
FILMED
1-77

APPENDIX L

SOFTWARE DOCUMENTATION

AND USER'S MANUAL

MULTIPLEXER DRIVER PROGRAM

FOR THE VARIAN 620i COMPUTER

SOFTWARE DOCUMENTATION AND USER'S MANUAL
MULTIPLEXER DRIVER PROGRAM
FOR THE VARIAN 620i COMPUTER

A. THE OVERALL DATA ACQUISITION SYSTEM

A Varian 620i computer with 4096 X 16 bits of memory and a teletype was interfaced to an A/D converter, then to a differential multiplexer capable of multiplexing 64 input channels. A block diagram of this data acquisition system is given in Figure L-1.

B. ELECTRA PHYSICS MULTIPLEXER AND A/D CONVERTER

The specifications for this equipment are briefly stated below.

1. Interface with Varian 620i computer, 3 commands.

(1) Transmit MPX address and gain.

(2) Sense if A/D conversion is complete.

(3) Read A/D converter.

2. Multiplexer

(1) 64 differential input channels with ± 15 V maximum allowed voltage on any input lead.

(2) Turn on time for the multiplexer switches is 1.5 microseconds.

3. Amplifier

(1) Thermal drift 0.6 microvolts/degree C.

(2) Slew rate and time constant adjustable by changes of capacitance, nominal .01 seconds.

(3) Long term and short term amplifier drift of less than 10 microvolts over a one-year period.

(4) Gain values selected for the μA725 amplifier.

		Max. Signal In	Value of LSB
Highest Gain	24.10	± 409.6 mv	.05 mv
Intermediate	12.05	± 819.2 mv	-1 mv
Lowest	1.205	± 8.192 Volts	1.0 mv
		± 8192 mv	

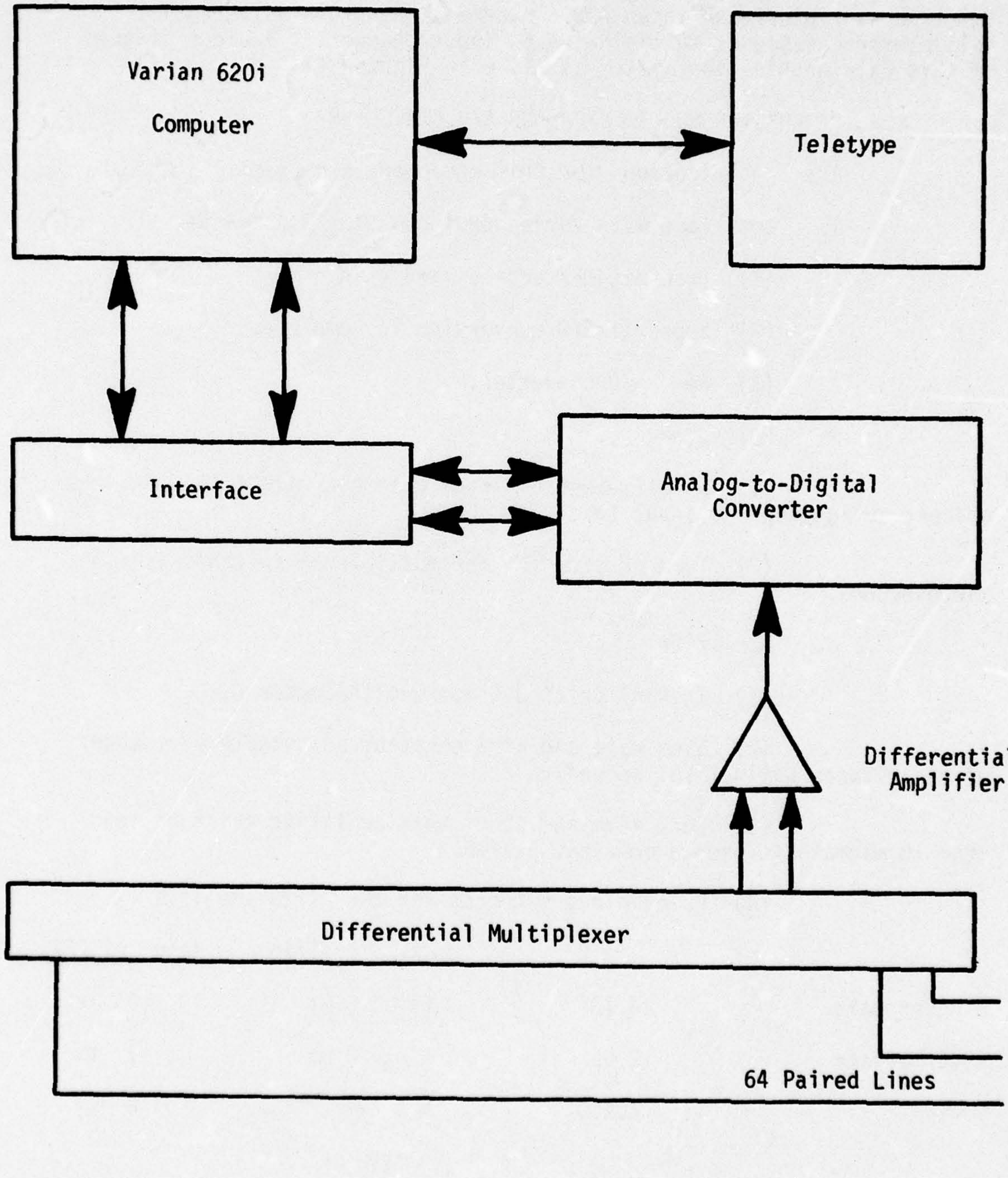


FIGURE L-1. BLOCK DIAGRAM OF DATA ACQUISITION SYSTEM

C. OPERATING PROCEDURES

The program was designed to scan, in whatever order desired, any selected sequence of the multiplexer channels. It was also designed to read each channel N times and print the average result. N is selectable by the user.

Starting at location 400 (octal)* a list of 64 multiplexer addresses and gains are placed as data.

Rules: (1) Always start with 177.

(2) The next octal digit sets gain

7 = 24.1, 6 = 12.05 and 5 = 1.205.

(3) The last 2 digits designate the channel - 1 in octal.

Examples

(Octal)		Decimal	Decimal
177700	=	channel 1 gain	24.10
177600	=	channel 1 gain	12.05
177500	=	channel 1 gain	1.205
177706	=	channel 7 gain	24.10
177722	=	channel 19 gain	24.10
177740	=	channel 32 gain	24.1
177540	=	channel 32 gain	1.205

Space is made available for more than 64 designated channels in case that the operator wishes to repeat selected channels. Any order or arrangement of addresses and gain is feasible in location 400_8 through 747_8. LIMC, the word in location 773_8, designates the number of locations to scan. The program will start at 400 and go to 400+ the contents of LIMC.

---

* Note all numbers in the program and this appendix are in the octal or base 8 designation, unless otherwise designated.

The program starts at location 1000 with a timer which waits for approximately the number of seconds set in T1 (location 761) between each scan of the address list. The program then moves to location 1025 and begins scanning.

Each channel is read for the number of times set in LIM (location 1022) and the resultant number is divided by the contents of LIM and printed.

The output format is in decimal and is 2 spaces, 2 integers which are the channel #, 2 spaces, 2 more integers which are the gain exponent, 2 spaces, + or - sign 3 digits, decimal point and the 2 final digits of the reading.

Example:

```
05  00  + 323.25

03  01  - 224.55

04  02  -  32.44
```

Intepretation:

Channel 5	decimal OK	+323.25 millivolts
Channel 3	move decimal 1 right	-2245.5 millivolts
Channel 4	move decimal point 2 right	-3244 millivolts

For loading program and/or making changes to the parameters refer to the computer instruction manuals by Varian. The program listing is given on pages L-7 through L-23.

SYMBØLS

```
0  001763 R  SUBB
0  001762 R  SUBA
0  001752 R  SUBT
0  001740 R  CHEX
0  001737 R  BB
0  001733 R  B
0  001712 R  B1B
0  001677 R  XBTD
1  001672 R  XDSU
0  001641 R  XDAD
0  001616 R  QSIN
0  001615 R  DSIN
0  001614 R  DVDN
0  001613 R  DVSR
0  001612 R  XR
0  001611 R  K14
1  001606 R  XDIV
0  001603 R  XERR
0  001561 R  ADJ
0  001550 R  TEST
0  001546 R  NEGU
0  001521 R  PØSU
0  001502 R  TØP
0  001465 R  XDCØ
0  001452 R  XB88
0  001405 R  XB8D
0  001376 R  PL
0  001375 R  MIN
0  001374 R  PD
0  001373 R  SVX
0  001372 R  SP
0  001371 R  TEMC
0  001370 R  TEMB
0  001367 R  TEMA
0  001361 R  SCL5
0  001350 R  SCXT
0  001325 R  SCAL
0  001322 R  RECØ
0  001306 R  DØ
0  001303 R  DØN
0  001302 R  S2
0  001301 R  S1
1  001270 R  ARIT
0  001263 R  PLUS
0  001245 R  SIGN
0  001177 R  ØPTB
0  001157 R  ØPTA
0  001156 R  LF
0  001155 R  CR
0  001144 R  CRLF
```

1	001137	R	ØTPT
0	001135	R	ØUT
0	001101	R	PRIN
0	001040	R	GØRU
0	001026	R	FØRE
0	001025	R	READ
0	001024	R	SUM2
1	001023	R	SUM
1	001022	R	LIM
0	001021	R	BLK
0	001011	R	GØ
0	001003	R	FSTE
0	001002	R	RUNE
0	001001	R	INNE
0	001000	R	STAR
0	000774	R	KØN1
0	000773	R	LIMC
0	000772	R	TEMP
0	000771	R	CØN3
0	000770	R	ØNE
0	000767	R	IMS1
0	000766	R	IMS2
0	000765	R	CØN2
0	000764	R	CØN1
0	000763	R	T3
0	000762	R	T2
0	000761	R	T1
0	000760	R	NCTR
0	000757	R	IMSK
1	000756	R	TENK
0	000755	R	SVEB
0	000754	R	LIT5
0	000753	R	LIT4
0	000752	R	LIT3
0	000751	R	LIT2
0	000750	R	LIT1
0	000400	R	CHGN
0	000001		$PU
0	000001		$LIS
0	000000		$MDV
0	000020		NBIT

```
           000020    NBIT   ,SET    ,16
           000000    $MDV   ,SET    ,0
           000001    $LIS   ,SET    ,1
           000001    $PU    ,SET    ,1
*
*     MPX SCAN AND A TO D CVT
*
000400                      ,ORG    ,0400
000400     177700    CHGN   ,DATA   ,0177700,0177701,0177702,0177703,017770
000401     177701
000402     177702
000403     177703
000404     177704
000405     177705
000406     177706           ,DATA   ,0177706,0177707,0177710,0177711,017771
000407     177707
000410     177710
000411     177711
000412     177712
000413     177713
000414     177714           ,DATA   ,0177714,0177715,0177716,0177717,017772
000415     177715
000416     177716
000417     177717
000420     177720
000421     177721
000422     177722           ,DATA   ,0177722,0177723,0177724,0177725,017772
000423     177723
000424     177724
000425     177725
000426     177726
000427     177727
000430     177730           ,DATA   ,0177730,0177731,0177732,0177733,017773
000431     177731
000432     177732
000433     177733
000434     177734
000435     177735
000436     177736           ,DATA   ,0177736,0177737,0177740,0177741,017774
000437     177737
000440     177740
000441     177741
000442     177742
000443     177743
000444     177744           ,DATA   ,0177744,0177745,0177746,0177747,017775
000445     177745
000446     177746
000447     177747
000450     177750
000451     177751
000452     177752           ,DATA   ,0177752,0177753,0177754,0177755,017775
000453     177753
000454     177754
000455     177755
```

```
000456  177756
000457  177757
000460  177760                ,DATA   ,0177760,0177761,0177762,0177763,017776
000461  177761
000462  177762
000463  177763
000464  177764
000465  177765
000466  177766                ,DATA   ,0177766,0177767,0177770,0177771,017777
000467  177767
000470  177770
000471  177771
000472  177772
000473  177773
000474  177774                ,DATA   ,0177774,0177775,0177776,0177777
000475  177775
000476  177776
000477  177777
*
*       TIMER AND START
*
000750                        ,ØRG    ,0750
000750  000200        LIT1    ,DATA   ,128
000751  000002        LIT2    ,DATA   ,2
000752  000004        LIT3    ,DATA   ,4
000753  000060        LIT4    ,DATA   ,48
000754  177777        LIT5    ,DATA   ,0177777
000755  000000        SVEB    ,DATA   ,0
000756  023420        TENK    ,DATA   ,10000
000757  077777        IMSK    ,DATA   ,077777
000760  000000        NCTR    ,DATA   ,0
000761  001750        T1      ,DATA   ,1000     SECØNDS WAIT BETWEEN READS
000762  001744        T2      ,DATA   ,996
000763  000135        T3      ,DATA   ,93
000764  140000        CØN1    ,DATA   ,0140000
000765  020000        CØN2    ,DATA   ,0020000
000766  000300        IMS2    ,DATA   ,0300
000767  000077        IMS1    ,DATA   ,077
000770  000001        ØNE     ,DATA   ,01
000771  037777        CØN3    ,DATA   ,037777
000772  000000        TEMP    ,DATA   ,0
000773  000100        LIMC    ,DATA   ,0100
000774  000077        KØN1    ,DATA   ,077
001000                        ,ØRG    ,01000
001000  020761        START   ,LDB    ,T1     BEGIN TIMER
001001  010762        INNER   ,LDA    ,T2
001002  030763        RUNER   ,LDX    ,T3
001003  005000        FSTER   ,NØP    ,
001004  005344                ,DXR    ,
001005  001040                ,JXZ    ,GØ
001006  001011 R
001007  001000                ,JMP    ,FSTER
001010  001003 R
*       10.8 MICRØSEC INNER LØØP
```

```
001011  005311     G0     ,DAR   ,
001012  001002            ,JAP   ,RUNER
001013  001002 R
001014  005322            ,DBR   ,
001015  001020            ,JBZ   ,READY
001016  001025 R
001017  001000            ,JMP   ,INNER
001020  001001 R
*
*     SET FIRST CHANNEL
*        THEN READ ALL CHANNELS
*
001021  000000     BLK    ,DATA  ,0
001022  000100     LIM    ,DATA  ,64
001023  000000     SUM    ,DATA  ,0
001024  000000     SUM2   ,DATA  ,0
001025  031021     READY  ,LDX   ,BLK
001026  015400     FØRE   ,LDA   ,CHGN,1
001027  005211            ,CPA   ,
001030  103162            ,ØAR   ,062
001031  101062            ,SEN   ,062,*
001032  001031 R
001033  005001            ,TZA   ,
001034  051023            ,STA   ,SUM
001035  051024            ,STA   ,SUM2
001036  141022            ,SUB   ,LIM
001037  050760            ,STA   ,NCTR
*
*        MAIN READ LØØP READS LIM TIMES
*
001040  015400     GØRUN  ,LDA   ,CHGN,1
001041  005211            ,CPA   ,
001042  103162            ,ØAR   ,062
001043  101062            ,SEN   ,062,*
001044  001043 R
001045  005000            ,NØP   ,
001046  005000            ,NØP   ,
001047  005000            ,NØP   ,
001050  005000            ,NØP   ,
001051  005000            ,NØP   ,
001052  005000            ,NØP   ,
001053  005000            ,NØP   ,
001054  005000            ,NØP   ,
001055  005000            ,NØP   ,
001056  005000            ,NØP   ,
001057  005000            ,NØP   ,
001060  102562            ,CIA   ,062
001061  001010            ,JAZ   ,GØRUN
001062  001040 R
001063  150771            ,ANA   ,CØN3
001064  005012            ,TAB   ,
001065  005001            ,TZA   ,
001066  002000            ,CALL  ,XDAD,SUM
001067  001641 R
```

```
001070  001023 R
001071  051023          ,STA   ,SUM
001072  061024          ,STB   ,SUM2
001073  040760          ,INR   ',NCTR
001074  010760          ,LDA   ,NCTR
001075  001010          ,JAZ   ,PRINT
001076  001101 R
001077  001000          ,JMP   ,GØRUN
001100  001040 R
*    PRINT THE LINE ØF DATA
*
001101  002000   PRINT  ,CALL  ,CRLF
001102  001144 R
001103  015400          ,LDA   ,CHGN,1
001104  150767          ,ANA   ,IMS1
001105  120770          ,ADD   ,ØNE
001106  002000          ,CALL  ,XBTD
001107  001677 R
001110  002000          ,CALL  ,ØPTA
001111  001157 R
*     THE CHANNEL NØ IS PRINTED
001112  015400          ,LDA   ,CHGN,1
001113  005211          ,CPA   ,
001114  150766          ,ANA   ,IMS2
001115  004306          ,ASRA  ,6
001116  002000          ,CALL  ,XBTD
001117  001677 R
001120  002000          ,CALL  ,ØPTA
001121  001157 R
*    THE EXPØNENT IS PRINTED
001122  002000          ,CALL  ,SCALE
001123  001325 R
001124  002000          ,CALL  ,ØPTB
001125  001177 R
001126  005144          ,IXR   ,
001127  005041          ,TXA   ,
001130  140773          ,SUB   ,LIMC
001131  001010          ,JAZ   ,START
001132  001000 R
001133  001000          ,JMP   ,FØRE
001134  001026 R
*
*     ØUTPUT ØNE CHAR FRØM A TØ TTY
*
001135  103101   ØUT    ,ØAR   ,01
001136  001000          ,JMP   ,*
001137  001136 R
001137           ØTPT   ,BES   ,0
001140  101101          ,SEN   ,0101,ØUT
001141  001135 R
001142  001000          ,JMP   ,*-2
001143  001140 R
*
*   CARRIAGE RETURN AND LINE FEED
```

```
*
001144  000000     CRLF  ,ENTRY,
001145  011155           ,LDA    ,CR
001146  002000           ,CALL   ,ØTPT
001147  001137 R
001150  011156           ,LDA    ,LF
001151  002000           ,CALL   ,ØTPT
001152  001137 R
001153  001000           ,JMP*   ,CRLF
001154  101144 R
001155  000015     CR    ,DATA   ,015
001156  000012     LF    ,DATA   ,012
*
*      ØUTPUT2SPACES AND NCHARS FRØM A N IN B
*
001157  000000     ØPTA  ,ENTRY,
001160  061367           ,STB    ,TEMA
001161  011372           ,LDA    ,SP
001162  002000           ,CALL   ,ØTPT
001163  001137 R
001164  011372           ,LDA    ,SP
001165  002000           ,CALL   ,ØTPT
001166  001137 R
001167  021367           ,LDB    ,TEMA
001170  004450           ,LLRL   ,8
001171  061371           ,STB    ,TEMC
001172  020751           ,LDB    ,LIT2
001173  002000           ,CALL   ,DØN
001174  001303 R
001175  001000           ,JMP*   ,ØPTA
001176  101157 R
*
*      ØUTPUT THE DATA WØRD
*
001177  000000     ØPTB  ,ENTRY,
001200  051367           ,STA    ,TEMA
001201  061370           ,STB    ,TEMB
001202  002000           ,CALL   ,CHEX
001203  001740 R
001204  011372           ,LDA    ,SP
001205  002000           ,CALL   ,ØTPT
001206  001137 R
001207  011372           ,LDA    ,SP
001210  002000           ,CALL   ,ØTPT
001211  001137 R
001212  002000           ,CALL   ,SIGN
001213  001245 R
001214  021370           ,LDB    ,TEMB
001215  011367           ,LDA    ,TEMA
001216  002000           ,CALL   ,XDIV,TENK
001217  001606 R
001220  000756 R
001221  051370           ,STA    ,TEMB
001222  005021           ,TBA    ,
```

```
001223  120753            ,ADD    ,LIT4
001224  002000            ,CALL   ,0TPT
001225  001137 R
001226  011370            ,LDA    ,TEMB
001227  002000            ,CALL   ,XBID
001230  001677 R
001231  061371            ,STB    ,TEMC
001232  020751            ,LDB    ,LIT2
001233  002000            ,CALL   ,D0N
001234  001303 R
001235  011374            ,LDA    ,PD
001236  002000            ,CALL   ,0TPT
001237  001137 R
001240  020751            ,LDB    ,LIT2
001241  002000            ,CALL   ,D0N
001242  001303 R
001243  001000            ,JMP*   ,0PTB
001244  101177 R
*
*       F0RM THE SIGN + 0R -
*
001245  000000    SIGN    ,ENTRY,
001246  011367            ,LDA    ,TEMA
001247  001002            ,JAP    ,PLUS
001250  001263 R
001251  021370            ,LDB    ,TEMB
001252  002000            ,CALL   ,XDC0
001253  001465 R
001254  061370            ,STB    ,TEMB
001255  051367            ,STA    ,TEMA
001256  011375            ,LDA    ,MIN
001257  002000            ,CALL   ,0TPT
001260  001137 R
001261  001000            ,JMP*   ,SIGN
001262  101245 R
001263  011376    PLUS    ,LDA    ,PL
001264  002000            ,CALL   ,0TPT
001265  001137 R
001266  001000            ,JMP*   ,SIGN
001267  101245 R
*
*       MULTIPLY AB BY 5
*
001270  000000    ARITH   ,ENTRY,
001271  051301            ,STA    ,S1
001272  061302            ,STB    ,S2
001273  004402            ,LASL   ,2
001274  002000            ,CALL   ,XDAD,S1
001275  001641 R
001276  001301 R
001277  001000            ,JMP*   ,ARITH
001300  101270 R
001301  000000    S1      ,DATA   ,0
001302  000000    S2      ,DATA   ,0
```

```
*
*     PRINT N CHARS FROM B
*
001303  000000     DON    ,ENTRY,
001304  071373            ,STX    ,SVX
001305  005024            ,TBX    ,
001306  005001     D0     ,TZA    ,
001307  021371            ,LDB    ,TEMC
001310  004444            ,LLRL   ,4
001311  061371            ,STB    ,TEMC
001312  120753            ,ADD    ,LIT4
001313  002000            ,CALL   ,OTPT
001314  001137 R
001315  005344            ,DXR    ,
001316  001040            ,JXZ    ,REC0
001317  001322 R
001320  001000            ,JMP    ,D0
001321  001306 R
001322  031373     REC0   ,LDX    ,SVX
001323  001000            ,JMP*   ,DON
001324  101303 R
*
*     GET PROPER SCALE
*
001325  000000     SCALE  ,ENTRY,
001326  011023            ,LDA    ,SUM
001327  021024            ,LDB    ,SUM2
001330  002000            ,CALL   ,XDIV,LIM
001331  001606 R
001332  001022 R
001333  060772            ,STB    ,TEMP
001334  005001            ,TZA    ,
001335  051023            ,STA    ,SUM
001336  010765            ,LDA    ,CON2
001337  140772            ,SUB    ,TEMP
001340  051024            ,STA    ,SUM2
001341  001002            ,JAP    ,SCXT
001342  001350 R
001343  010754            ,LDA    ,LIT5
001344  051023            ,STA    ,SUM
001345  011024            ,LDA    ,SUM2
001346  150757            ,ANA    ,IMSK
001347  051024            ,STA    ,SUM2
001350  015400     SCXT   ,LDA    ,CHGN,1
001351  005211            ,CPA    ,
001352  150766            ,ANA    ,IMS2
001353  001010            ,JAZ    ,SCL5
001354  001361 R
001355  021024            ,LDB    ,SUM2
001356  011023            ,LDA    ,SUM
001357  001000            ,JMP*   ,SCALE
001360  101325 R
001361  011023     SCL5   ,LDA    ,SUM
001362  021024            ,LDB    ,SUM2
```

```
001363  002000             ,CALL   ,ARITH
001364  001270 R
001365  001000             ,JMP*   ,SCALE
001366  101325 R
001367  000000      TEMA   ,DATA   ,0
001370  000000      TEMB   ,DATA   ,0
001371  000000      TEMC   ,DATA   ,0
001372  000040      SP     ,DATA   ,32
001373  000000      SVX    ,DATA   ,0
001374  000256      PD     ,DATA   ,'.'
001375  000255      MIN    ,DATA   ,'-'
001376  000253      PL   ,DATA   ,'+'
*
*     FIXED POINT DP INTEGER CONVERSION
*
001377  011453             ,LDA    ,XB88+1 BIN TO DEC CONVERSION
001400  002000             ,CALL   ,XBTD
001401  001677 R
001402  005041             ,TXA    ,
001403  031454             ,LDX    ,XB88+2
001404  001000             ,PZE    ,001000
001405  000000      XB8D   ,ENTR   ,
001406  002004             ,JANM   ,XDC0
001407  001465 R
001410  051452             ,STA    ,XB88
001411  061453             ,STB    ,XB88+1
001412  071454             ,STX    ,XB88+2
001413  006030             ,LDXI   ,077774
001414  077774
001415  071445             ,STX    ,XB88-5
001416  006030             ,LDXI   ,XB88+1
001417  001453 R
001420  071434             ,STX    ,*+12
001421  007400             ,ROF    ,
001422  005004             ,TZX    ,
001423  005041             ,TXA    ,
001424  004244             ,LRLA   ,4
001425  005014             ,TAX    ,
001426  011452             ,LDA    ,XB88
001427  021453             ,LDB    ,XB88+1
001430  041434             ,INR    ,*+4
001431  041434             ,INR    ,*+3
001432  002000             ,CALL   ,XDSU,*
001433  001672 R
001434  001434 R
001435  001004             ,JAN    ,*+7
001436  001444 R
001437  005144             ,IXR    ,
001440  051452             ,STA    ,XB88
001441  061453             ,STB    ,XB88+1
001442  001000             ,JMP    ,*-8
001443  001432 R
001444  006040             ,INRI   ,
001445  000000
```

```
001446  001001          ,JØF    ,XB8D-6
001447  001377 R
001450  001000          ,JMP    ,*-21
001451  001423 R
001452  000000   XB88   ,DATA   ,0,0,0,0461,013200,036,041100
001453  000000
001454  000000
001455  000461
001456  013200
001457  000036
001460  041100
001461  000003          ,DATA   ,3,03240,0,023420
001462  003240
001463  000000
001464  023420
*
*   XDCØ                        FIXED PØINT DØUBLE PRECISIØN CØMPLEMENT
*
001465  000000   XDCØ   ,ENTR   ,
001466  005211          ,CPA    ,
001467  001020          ,JBZ    ,*+8
001470  001477 R
001471  005222          ,CPB    ,
001472  005122          ,IBR    ,
001473  004041          ,LRLB   ,1
001474  004141          ,LSRB   ,1
001475  001000          ,JMP*   ,XDCØ
001476  101465 R
001477  005111          ,IAR    ,
001500  001000          ,JMP*   ,XDCØ
001501  101465 R
*
*   XDIV                        SØFTWARE DIVIDE
*
*                 A,B/MB [QUØTIENT] < A [REMINDER]
*                 A REG MEMØRY X IS UNCHANGED
*                 QUØTIENT IS ALWAYS TRUE
*                 REMAINDER IS SIGN ØF DIVIDEND [UNLESS R>0]
*
001502  071612   TØP    ,STX    ,XR                   SAVE XR
001503  005304          ,DECR   ,4                    SET SIGN INDICATØR
001504  001002          ,JAP    ,PØSU                 SET DIVIDEND PØS
001505  001521 R
001506  005244          ,CPX    , SET DSIN>NEG
001507  005222          ,CPB    , LØ ØRDER TWØ,S CØMPL
001510  005122          ,IBR    ,
001511  004041          ,LRLB   ,1                    SIGN>O
001512  004141          ,LSRB   ,1
001513  005211          ,CPA    , HI ØRDER TWØ,S CØMPL
001514  001020          ,JBZ    ,*+4
001515  001520 R
001516  001000          ,JMP    ,*+3
001517  001521 R
001520  005111          ,IAR    ,
```

```
001521  071615     P0SU  ,STX    ,DSIN             SAVE DIVDN SIGN
001522  051614           ,STA    ,DVDN             SAVE DIVDN
001523  031606           ,LDX    ,XDIV             GET ADDR 0F CALL SEQ
001524  035000           ,LDX    ,0,1              GET ADDR 0F PARAM
001525  015000           ,LDA    ,0,1              GET DIVIS0R
001526  031615           ,LDX    ,DSIN             GET DIVDN SIGN
001527  001002           ,JAP    ,*+5              SET DIVIS0R P0S
001530  001534 R
001531  005244           ,CPX    , SET QU0TIENT SIGN
001532  005211           ,CPA    , TW0,S C0MPL
001533  005111           ,IAR    ,
001534  051613           ,STA    ,DVSR             SAVE DIVIS0R
001535  011614           ,LDA    ,DVDN             GET DIVDN
001536  071616           ,STX    ,QSIN             SAVE QU0T SIGN
001537  031611           ,LDX    ,K14              SET CYCLE C0UNT
001540  004041           ,LRLB   ,1                ADJUST L0 0RDER (DELETE
001541  141613           ,SUB    ,DVSR             SUB DIVS0R
001542  007401           ,S0F    ,
001543  001002           ,JAP    ,XERR             JMP IF 0VERFL0W ERR0R
001544  001603 R
001545  007400           ,R0F    ,
001546  004441     NEGU  ,LLRL   ,1                DEVEL0P 14 QU0TIENT BITS
001547  121613           ,ADD    ,DVSR             (N0N REST0RING ALG0RITHM
001550  001040     TEST  ,JXZ    ,ADJ              JMP IF C0MPLETE
001551  001561 R
001552  005344           ,DXR    , C0UNT BITS
001553  001004           ,JAN    ,NEGU             JUMP IF NEG REMAINDER
001554  001546 R
001555  004441           ,LLRL   ,1                SHIFT QU0TOREM
001556  141613           ,SUB    ,DVSR             SUBTRACT DIVSR
001557  001000           ,JMP    ,TEST             G0 TEST
001560  001550 R
001561  004041     ADJ   ,LRLB   ,1                GET LAST QU0TIENT BIT
001562  001002           ,JAP    ,*+4              JMP IF 0R
001563  001566 R
001564  005122           ,IBR    , ELSE SET L0B
001565  121613           ,ADD    ,DVSR             REST0RE REMAINDER
001566  031616           ,LDX    ,QSIN             GET TRUE QU0TIENT
001567  001040           ,JXZ    ,*+4              JMP IF NEGATIVE QU0T
001570  001573 R
001571  005222           ,CPB    , ELSE SET P0SITIVE
001572  005322           ,DBR    ,
001573  005122           ,IBR    ,
001574  031615           ,LDX    ,DSIN             GET TRUE REMAINDER
001575  001040           ,JXZ    ,*+4              JMP IF REMAINDER NEG
001576  001601 R
001577  001000           ,JMP    ,*+4              ELSE LEAVE P0S
001600  001603 R
001601  005211           ,CPA    ,
001602  005111           ,IAR    ,
001603  041606     XERR  ,INR    ,XDIV             SET RETURN
001604  031612           LDX     ,XR
001605  001000           ,JMP*   ,XDIV             A,B0M; B>QU0T A>REM
001606  101606 R
```

```
001606                XDIV  ,BES   ,0               ENTRY
001607  001000              ,JMP   ,10P
001610  001502 R
001611  000016        K14   ,DATA  ,14
001612                XR    ,BSS   ,1               TEMP STØRAGE
001613                DVSR  ,BSS   ,1
001614                DVDN  ,BSS   ,1
001615                DSIN  ,BSS   ,1
001616                QSIN  ,BSS   ,1
*
*   XDAD                    FIXED PØINT DØUBLE PRECISIØN ADD/SUBIRACT
*
001617  071644              ,STX   ,XDAD+3          SAVE XR
001620  007400              ,RØF  , RESET ØF
001621  031641              ,LDX   ,XDAD
001622  035000              ,LDX   ,0,1             XR>ADDR ØF HI B
001623  051645              ,STA   ,XDAD+4          SAVE HI A
001624  005021              ,TBA  , GET LØ A
001625  125001              ,ADD   ,1,1             ADD LØ B
001626  006150              ,ANAI  ,077777          MASK SIGN
001627  077777
001630  005012              ,TAB  , SAVE RESULT
001631  005001              ,TZA  ,
001632  005511              ,AØFA , GET CARRY
001633  007400              ,RØF  , RESET ØF
001634  121645              ,ADD   ,XDAD+4          ADD HI A
001635  125000              ,ADD   ,0,1             ADD HI B
001636  041641              ,INR   ,XDAD            SET RETURN
001637  031644              ,LDX   ,XDAD+3          RESTØRE XR
001640  001000              ,JMP   ,0               RETURN
001641  000000
        001641 R      XDAD  ,EQU   ,*-1             ENTRY
001642  001000              ,JMP   ,*-19
001643  001617 R
001644  000000              ,DATA  ,0,0             TEMP STØRAGE
001645  000000
*
*   XDSU                    FIXED PØINT DØUBLE PRECISIØN SUBTRACT
*
001646  071675              ,STX   ,XDSU+3          SAVE XR
001647  007400              ,RØF  , RESET ØF
001650  031672              ,LDX   ,XDSU
001651  035000              ,LDX   ,0,1             XR-ADDR ØF HI B
001652  051676              ,STA   ,XDSU+4          SAVE HI A
001653  005021              ,TBA  ,
001654  006110              ,ØRAI  ,0100000         SET SIGN FØR CARRY
001655  100000
001656  145001              ,SUB   ,1,1             SUB LØ B
001657  006150              ,ANAI  ,077777          MASK SIGN
001660  077777
001661  005012              ,TAB  , SAVE RESULT
001662  005001              ,TZA  ,
001663  005711              ,SØFA , GET CARRY
001664  007400              ,RØF  , RESET ØF
```

```
001665 121676        ,ADD    ,XDSU+4         ADD HI A
001666 145000        ,SUB    ,0,1            SUB HI B
001667 041672        ,INR    ,XDSU           SET RETURN
001670 031675        ,LDX    ,XDSU+3         RESTØRE XR
001671 001000        ,JMP    ,0              RETURN
001672 000000
001672               ,ØRG    ,*-1
001672 000000  XDSU  ,ENTR , ENTRY
001673 001000        ,JMP    ,*-21
001674 001646 R
001675 000000        ,DATA   ,0,0            TEMP STØRAGE
001676 000000
*
*   XBTD                 FIXED PØINT INTEGER BIN TØ DEC CØNVERSIØN
*
001677 000000  XBTD  ,ENTR ,
001700 051733        ,STA    ,B
001701 071734        ,STX    ,B+1
001702 001002        ,JAP    ,*+4            JUMP IF PØSITIVE
001703 001706 R
001704 005211        ,CPA    , ELSE CØMPLEMTNT
001705 005111        ,IAR    , AND ADD ØNE
001706 005012        ,TAB    ,
001707 006030        ,LDXI   ,3              INITIALIZE CØUNT
001710 000003
001711 005001        ,TZA    ,
001712 002000  BIB   ,CALL   ,XDIV,BB
001713 001606 R
001714 001737 R
001715 061735        ,STB    ,*+16           SAVE BIN VALUE
001716 021736        ,LDB    ,*+16           GET PREVIØUS DIGITS
001717 004544        ,LLSR   ,4              ATTACH DIGIT TØ RESULT
001720 001040        ,JXZ    ,*+7            JUMP IF CØMPLETE
001721 001727 R
001722 005344        ,DXR    , ELSE CØUNT DIGITS
001723 061736        ,STB    ,*+11           SAVE DIGITS ASSEMBLED
001724 021735        ,LDB    ,*+9            GET BIN VALUE
001725 001000        ,JMP    ,BIB
001726 001712 R
001727 011733        ,LDA    ,*+4            RESTØRE AR
001730 031734        ,LDX    ,*+4            RESTØRE XR
001731 001000        ,JMP*   ,XBTD           RETURN
001732 101677 R
001733 000000  B     ,DATA   ,0,0,0,0        TEMP STØRAGE
001734 000000
001735 000000
001736 000000
001737 000012  BB    ,DATA   ,10             CØNSTANT
001740 000000  CHEX  ,ENTRY,
001741 015400        ,LDA    ,CHGN,1    IF CH1 SAVE
001742 150774        ,ANA    ,KØN1
001743 001002        ,JAP    ,SUBT
001744 001752 R
001745 011367        ,LDA    ,TEMA
```

```
   001746  051762         ,STA    ,SUBA
   001747  061763         ,STB    ,SUBB
   001750  001000         ,JMP*   ,CHEX
   001751  101740 R
   001752  011367   SUBT  ,LDA    ,TEMA       NØT CHI SUBTRACT
   001753  002000         ,CALL   ,XDSU,SUBA
   001754  001672 R
   001755  001762 R
   001756  051367         ,STA    ,TEMA
   001757  061370         ,STB    ,TEMB
   001760  001000         ,JMP*   ,CHEX
   001761  101740 R
   001762  000000   SUBA  ,DATA   ,0
   001763  000000   SUBB  ,DATA   ,0
           000000         ,END    ,
```

LITERALS

PØINTERS

SYMBØLS

```
1   001763 R  SUBB
1   001762 R  SUBA
1   001752 R  SUBT
1   001740 R  CHEX
1   001737 R  BB
1   001733 R  B
1   001712 R  B1B
1   001677 R  XBTD
1   001672 R  XDSU
1   001641 R  XDAD
1   001616 R  QSIN
1   001615 R  DSIN
1   001614 R  DVDN
1   001613 R  DVSR
1   001612 R  XR
1   001611 R  K14
1   001606 R  XDIV
1   001603 R  XERR
1   001561 R  ADJ
1   001550 R  TEST
1   001546 R  NEGU
1   001521 R  PØSU
1   001502 R  TØP
1   001465 R  XDCØ
1   001452 R  XB88
1   001405 R  XB8D
1   001376 R  PL
1   001375 R  MIN
1   001374 R  PD
1   001373 R  SVX
1   001372 R  SP
```

1	001371	R	TEMC
1	001370	R	TEMB
1	001367	R	TEMA
1	001361	R	SCLS
1	001350	R	SCXT
1	001325	R	SCAL
1	001322	R	REC0
1	001306	R	D0
1	001303	R	D0N
1	001302	R	S2
1	001301	R	S1
1	001270	R	ARIT
1	001263	R	PLUS
1	001245	R	SIGN
1	001177	R	0PTB
1	001157	R	0PTA
1	001156	R	LF
1	001155	R	CR
1	001144	R	CRLF
1	001137	R	0TPT
1	001135	R	0UT
1	001101	R	PRIN
1	001040	R	G0RU
1	001026	R	F0RE
1	001025	R	READ
1	001024	R	SUM2
1	001023	R	SUM
1	001022	R	LIM
1	001021	R	BLK
1	001011	R	G0
1	001003	R	FSTE
1	001002	R	RUNE
1	001001	R	INNE
1	001000	R	STAR
1	000774	R	K0N1
1	000773	R	LIMC
1	000772	R	TEMP
1	000771	R	C0N3
1	000770	R	0NE
1	000767	R	IMS1
1	000766	R	IMS2
1	000765	R	C0N2
1	000764	R	C0N1
1	000763	R	T3
1	000762	R	T2
1	000761	R	T1
1	000760	R	NCTR
1	000757	R	IMSK
1	000756	R	TENK
1	000755	R	SVEB
1	000754	R	LIT5
1	000753	R	LIT4
1	000752	R	LIT3
1	000751	R	LIT2

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1	000750	R	LITI
1	000400	R	CHGN
0	000001		$PU
0	000001		$LIS
0	000000		$MDV
0	000020		NBIT

-

APPENDIX M

CALIBRATION PROCEDURE FOR DATA ACQUISITION SYSTEMS

CALIBRATION PROCEDURE FOR DATA ACQUISITION SYSTEMS

A. PURPOSE

The purpose of this calibration procedure is to certify that the data acquisition systems used to record data for the Flexible Case/Grain Interaction Test Program meet the accuracy requirements specified in Paragraph 3.8.1.2 Of the program work statement.*

B. DESCRIPTION OF THE CALIBRATION PROCEDURE

This procedure shall be divided into three parts. First, the recording system shall be subjected to known voltages and its measured value compared against a laboratory standard voltmeter, whose calibration is traceable to the National Bureau of Standards. Secondly, a transducer simulator shall be calibrated to verify its stability and balance. Thirdly, as a data acquisition system check, the transducer simulator shall be installed in place of the transducer. A two step calibration step shall be applied from the simulator. The two values recorded shall be repeated a prescribed number of times to verify repeatability.

Calibration of the recording system alone and transducer simulator shall be conducted every three months. This interval may be extended to a maximum of 4-1/2 months. Calibration of the data acquisition system with simulator shall be conducted every week. If, after four calibrations, the data are acceptable, the calibration interval may be increased to one month.

C. APPLICABLE DOCUMENTS

Government Documents

Mil Q-9858A	Program Quality Assurance Requirements
Mil C-45662A	Calibration Requirements

ASPC

QCI-0203(d)	System Calibrations
QCI-0204(a)	Laboratory Calibrations
QCI-0205(c)	Laboratory Operations
QCI-0206(a)	Calibration Intervals

* This procedure was instituted at the time that a more stringent DAS accuracy requirement was levied and the new DAS (described in Appendix L) was assembled. The procedure was not used for the DAS described in Appendix G or in connection with any of the data discussed in this volume of the report

ASPC (cont)

QCI-0207	Calibration Procedures
QCI-2001(e)	Qualification Tags and Stickers
ACP 2259B	System Calibration
ACP 2260	Control Room Operations

D. APPLICABLE EQUIPMENT

Manufacture	Model	Description
Hewlett-Packard	3450B	Multifunction Meter
John P. Fluke	332A	D.C. Voltage Standard
John P. Fluke	335A	D.C. Voltage Standard
Leeds & Northrup	4232B	Wheatstone Bridge
Leeds & Northrup	8686	Potentiometer
Brooklyn, Inc.	-	Thermometer, Gages (0 to 120°F)

E. CALIBRATION OF THE RECORDING SYSTEMS (WITHOUT BRIDGE COMPLETION)

1. ASPC Test Operations Data Acquisition System

This system shall be calibrated in accordance with Aerojet Calibration Procedure 2259B and 2260.

2. ASPC Propellant Development Lab DAS Procedure

a. Using the shop standard precision voltage source apply voltages of 0.0, ± 1.00, ± 2.00, ± 3.00, ± 4.00, ± 5.00, ± 6.00, ± 7.00, ± 8.00, ± 9.00, ± 10.00, ± 20.00, ± 30.00, ± 40.00, ± 50.00, ± 60.00, ± 70.00, ± 80.00, ± 90.00, ± 100.00 millivolts ± 0.02 millivolts, to a randomly selected channel. All other channels shall be subjected to 0.00, ± 5.00, ± 10.00, ± 50.00, and ± 100.00 millivolts, ± 0.02 millivolts.

b. Repeat Paragraph 1 above after a 24 hour period twice, without adjustments.

c. Cross talk shall be checked on a randomly selected channel by subjecting adjacent channels to plus and minus overscale input voltages and recording any changes to the reading of the selected channel.

d. Common Mode Rejection

(1) D. C.

A common mode voltage of 10 volts D.C. shall be applied to an unbalanced input of 1,000 ohms of a randomly selected channel.

(2) A.C.

A common mode voltage of 5 volts RMS, 60 hz shall be applied to an unbalanced input Of 1,000 Ω of a randomly selected channel.

e. Acceptance Criteria

(1) Zero effects must be less than 2.00 millivolts. The DAS must be capable of reproducing the input voltage to within ± 0.1 millivolt or ±1.5% whichever is greater.

(2) Cross talk shall not exceed ± .1 millivolt of the value read on the selected channel just prior to the application of the overscale voltages.

(3) Common mode rejection shall be -80 db or better for both AC and DC.

F. CALIBRATION OF THE SIMULATOR

1. Purpose

The transducer simulator shall consist of two balanced 500 ohm resistors and a 550 ohm bridge unbalance resistor. The purpose of the simlator is to serve as a stable source which can be installed in place of the transducer so that an expected output can be applied.

2. Calibration

The purpose of the calibration is to verify that the simulator is stable over time. Therefore, an excitation voltage of 10.0000, ± 0.0002 volts shall be applied and the voltage at the midpoint of the simulator shall be measured with and without the shunt resistor. Ten readings shall be taken for each 24 hours for three consecutive days. These readings shall be taken at +30, +60, and +90°F.

3. Specifications

The voltage measurements taken at each temperature shall not vary more than ± 0.2 mv for any corresponding readings taken. The same shall be true for the measurements taken with the shunt step applied.

G. SYSTEM SIMULATION

1. Purpose

The purpose of the system simulation is to provide a cursory check of the system excluding the transducer. It will serve to check system components and verify proper operation of the bridge completion network. It also will provide a means of monitoring and checking system drift.

2. Calibration

a. *First System Simulation*

To assure that the common mode voltage does not exceed 5 volts RMS AC, the AC voltage on all input lines will be measured with respect to ground when the DAS is first attached to the motor instrumentation. As a further check dummy bridges will be limit checked to $\pm$ 0.1 mv. The DAS will be programmed to check these bridges and flag the system if any of the outputs exceed the limits.

(1) Install the simulator in place of the transducer.

(2) Read the voltage from each output leg to the negative input leg.

(3) Take ten readings of the zero and shunt step. (A reading is defined as the average of 100 samples or greater).

(4) Record all data.

(5) Repeat for each channel.

(6) Wait 24 hours.

(7) Repeat paragraphs (1) through (6) three times.

b. *Subsequent System Simulations*

Perform paragraphs (1) through (5) above one time.

3. Specifications

a. First System Simulation

(1) Calculate the mean and standard deviation of the sampled readings at the zero and the shunt step values.

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \,, \qquad S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}}$$

(2) "S" must be less than $\pm$ 0.2 millivolt or 4% whichever is greater.

(3) The value of $\bar{X}_0$ and $\bar{X}_{shunt}$ and S then is to be recorded and compared with each subsequent system simulation.

b. Subsequent Simulations

(1) Repeat paragraph a(1) above.

(2) The recorded values of $\overline{X}_o$ and $\overline{X}_{shunt}$ shall be within $\pm$ 0.2 millivolts or 3.0% whichever is greater of the original values of $\overline{X}_o$ and $\overline{X}_{shunt}$. The value of S_o and S_{shunt} shall be checked to determine the standard deviation and shall not exceed $\pm$ 0.2 mv or 3.0% whichever is greater.

H. FAILURE TO MEET SPECIFICATIONS

1. Recording System

If the recording system fails to meet specifications, it shall be adjusted and/or repaired until it does meet specifications. Or, if it is determined that, once the system is in operation, it is unfeasible to move the equipment to the laboratory, the system and/or data shall be adjusted to account for obvious shifts in calibration.

2. Transducer Simulation

If the transducer simulator fails to meet specifications, it (they) shall be reworked or replaced.

3. System Simulation

Should the system simulation fail to meet specifications, the recording system shall be checked to verify its proper operation. If the recording system is within specifications, an attempt will be made to repair the bridge completion network and/or its associated wiring. If the channel cannot be brought into specification, it shall be suspended from service.

APPENDIX N

PRESSURE CALIBRATION AND STABILITY TESTING OF GAGES

PRESSURE CALIBRATION AND STABILITY TESTING OF GAGES

This appendix describes the steps followed while conducting the pressure calibrations and stability tests of the gages in Motor No. 1.

A. MOTOR PREPARATION AND TEST SET-UP

1. Connect gage and test circuits to the DAS according to the channel assignments given in Table N-1.

2. Connect thermocouples to a separate strip-chart recorder according to the channel assignments given in Table N-2.

3. Calibrate and connect 100 psi pressure transducer onto pressure line and to DAS channel 60. Provide shunt step for certain % of F.S.

4. Connect Heise gage near pressure controls.

5. Test pressure system to ensure that it will hold and maintain 0 to 50 psi nitrogen gas pressure for times up to 50 minutes. Conduct leak check at 15 psi gas pressure.

B. DAS STABILITY TESTS

1. Take readings according to the Integrated Test Instructions (I.T.I.) given below, (Table N-3). This I.T.I. will be initiated each week during the stability tests.

2. Conduct tests six times over a period of 15 weeks.

3. Reduce test data in terms of means ($\overline{X}$) and standard deviation (S).

4. Analyze data for drift prior to continuing.

C. PRESSURE CALIBRATION OF GAGES

1. Take readings according to the Integrated Test Instructions given below.

2. Record all zero data five times with the motor vented to the atmosphere. (Data sampling time: approximately 1 hour).

3. Record all zero data two times in closed pressure system. (Data sampling time: 22 minutes).

4. Conduct the first set of pressure calibration tests according to the following sequence of test pressures: 0 psi, 5 psi, 10 psi, 20 psi, 30 psi, 40 psi, 50 psi, 20 psi, 10 psi, 0 psi. (Each pressure increment took 25 to 40 minutes to stabilize).

5. After system is stabilized, hold for 10 minutes prior to first data recordings.

6. Take two sampling runs (22 minutes) at given pressure.

7. Cognizant engineer will evaluate data to determine need for possible additional data sampling.

8. Continue to next pressure level and repeat steps e through g.

9. After completing the test series (see d above) allow one day for grain recovery

10. Conduct second set of pressure calibration tests.

11. Reduce the test data as discussed in Section 11 of the report.

D. INTEGRATED TEST INSTRUCTIONS

A copy of these detailed test instructions are given in Table N-3.

TABLE N-1

DAS CHANNEL ASSIGNMENTS FOR GAGES AND TEST CIRCUITS

Channel No.	Gage on Circuit
1	Zero Reference Channel
2	Empty
3	N2-2
4	N10-2
5	N5-2
6	N3-1
7	Empty
8	Empty
9	N9-2
10	N4-1
11	N1-1
12	Empty
13	N11-2
14	S-8
15	N2-1
16	S-11
17	S-6
18	N8-2
19	S-14
20	N9-1
21	N11-1
22	S-9
23	N15-1
24	N10-1
25	N1-2
26	S-12
27	S-5
28	N4-2
29	N5-1
30	N15-2
31	S-7
32	N8-1
33	N6-1
34	S-3
35	S-4

Channel No.	Gage on Circuit
36	N7-1
37	S-10
38	S-1
39	N3-2
40	Power supply voltage divider
41	Power supply voltage divider
42(+11.40V)	Dummy Resistor Full Bridges
43(-11.00V)	"
44(-10.80V)	"
45(+11.05V)	"
46 392.75	Volt Div.
47 400 mv	Std. Voltage
48	Empty
49	N7-2
50	M6-2
51	LVDT-1
52	LVDT-2
53	LVDT-3
54	LVDT-4
55	LVDT-5
56	LVDT-6
57	Potentiometer-7 (0°)
58	Potentiometer-8 (135°)
59	Potentiometer-9 (180°)
60	Pressure transducer

Gages S-2 and S-13 were bad gages and were not connected.

TABLE N-2

RECORDER CHANNEL ASSIGNMENTS FOR THERMOCOUPLES

Channel Number	Thermocouple Number
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	Blank*
13	20
14	21
15	22
16	16
17	Blank**
18	18
19	19
20	12
21	14
22	15

* Thermocouple 13 not installed

** Thermocouple 17 bad

AGCS 1900-15 (S)

AEROJET SOLID PROPULSION COMPANY
INTEGRATED TEST INSTRUCTIONS

ITI NO. 00845	TABLE N-3	PAGE 1 OF 4
FACILITY	FLEXIBLE CASE GRAIN INTERACTION GAGE STABILITY TESTS	PREPARED BY A. I. Imagire DATE 7/7/75
TEST NO		APPROVED
UNIT S/N		APPROVED
		REFERENCE DAS System Certification 5/14/75

INITIAL T.D.	INITIAL INSP.	OPERATION

GENERAL INSTRUCTIONS

As each step is completed, the individual performing the test or examination shall initial the space provided as verification of completion. All entries shall be made in a legible manner, in ink, preferably black.

When a characteristic of this checklist is not complied with, record its number in the operations column and notify the cognizant engineer and Inspection, who will initiate an I. R. Record on the I.R. information that is necessary to give a complete description of the discrepancy.

During actual processing, revisions to the checklist or requirements contained therein will be made in the operations column. Changes will be initiated by the cognizant test engineer and entered in ink. Quality Engineering approval of the change must be obtained prior to use of the data for acceptance purposes.

Upon completion of this checklist, it shall be delivered to the Project Engineer.

SPECIAL INSTRUCTIONS

Notify AFPRO/QE J. Simperman, 355-3885, at beginning of test.

1.0 PROCEDURE

1.1 System Simulated

1.1.1 The DAS shall be checked with the simulated transducer networks each week until four consecutive checks indicate that the data remains unchanged, at which time the interval shall be changed to one month. The mean value shall not deviate from the baseline data more than $\pm$ 0.10 mv or $\pm$ 1.5% of reading, whichever is larger. Ten readings shall be taken at each simulation.

1.2 Transducer Output Measurement

1.2.1 The transducer excitation voltage must be applied for a minimum of 16 hours but not more than 24 hours prior to taking measurements. The excitation to the transducers must be off for a minimum of 24 hours prior to application of voltage.

INITIAL		OPERATION
T. D.	INSP.	

1.3 Sequence of Operation

1.3.1 The weekly sequence of operation shall be as follows:

1.3.1.1 On Monday (or Tuesday) of each week system simulation shall be performed. There is no warm-up on-off period restriction. The data shall be compared to data established during system certification, if the data falls within specification. Measure and record common mode voltage.

1.3.1.2 Re-hook up the transducers and at 1600 hours turn on excitation voltage. Insure that it is 28.00 VDC.

1.3.1.3 On the day following simulation and at least 16 hours but not more than 24 hours after application of excitation voltage take five readings of each channel. Record time for each reading. Record barometric pressure to the nearest hundredth of an inch (Mather AFB 364-4377). Attach temperature recorder chart to data. Turn power off.

1.3.1.4 Wait 24 hours and repeat steps 2 and 3.

1.4 This I.T.I. shall be initiated each week.

2.0 SYSTEM SIMULATION

2.0.1 Date and time started ______________________________.
Date Time

2.0.2 Verify DAS is in calibration.

2.0.3 Hook DAS inputs to transducer simulators.

2.0.4 Turn on bridge excitation. Set to 28.00 VDC.

2.0.5 Measure AC voltage on each input line to ground. Verify that the common mode voltage is less than 5V. RMS.

2.0.6 Take ten (10) readings on simulated channels.

2.0.7 Secure system. Turn off power.

2.0.8 Reterminate DAS inputs to transducers.

Date and time completed ______________________________.
Date Time

INITIAL		OPERATION
T.O.	INSP.	

2.0.9 Verify that system simulation $\overline{x}$ and sigma values meet specification requirements of certification data ± ________ mv.

2.1 Transducer Output Measurement

NOTE: This part of the procedure is not to be started unless the transducer excitation has been turned off for at least 24 hours. When excitation is turned on readings may not be taken until the excitation has been on for a minimum of sixteen (16) hours but not more than twenty-four (24) hours.

2.1.1 First readings -

2.1.1.1 At 1600 hours on the day prior to taking readings turn on transducer excitation set at +28.00 VDC.

Date and time turned on ________________
Date Time

Date and time system will be ready for

readings ________________
Date Time

2.1.1.2 At time and date system is ready to record (Para. 2.1.1.1 above) take five readings on DAS.

Record date and time on printout.

2.1.1.3 Call Mather AFB 364-4377 for barometric pressure and record ____________ psia.

2.1.1.4 Remove temperature record noting date and time removed and attach to printout.

2.1.1.5 Shut off excitation. Time and date

____
Date Time

2.1.1.6 Deliver data to instrument engineer in charge.

INITIAL		OPERATION
T.D.	INSP.	

2.1.2 Second readings -

2.1.2.1 Verify power has been off for a minimum of 24 hours (Para. 2.1.1.4). Record date and time ______ ______.
Date Time

2.1.2.2 Turn on transducer excitation. Set for 28.00 VDC. Record date and time power turned on ______ ______.
Date Time

2.1.2.3 System ready for readings at ______ ______. (16 hours from date and time in 2.1.2.2).
Date Time

2.1.2.4 Take readings at time specified in Para. 2.1.2.3 above. Record all channels five times. Note date and time on printout.

Date and time data recorded ______ ______.
Date Time

2.1.2.5 Record barometric pressure (call Mather AFB 364-4377) on printout.

2.1.2.6 Strip temperature record and affix to printout.

2.1.2.7 Shut off excitation. Record date and time ______ ______.
Date Time

2.1.2.8 Deliver data to instrumentation engineer.

3.0 Verify ITI complete and signed off and N/A initialed.

____
Test Engineer Date

APPENDIX O

TRANSDUCER STABILITY

LETTER FROM

E. KONIGSBERG

JUNE 24, 1976

KONIGSBERG INSTRUMENTS, INC.

2000 East Foothill Boulevard   Pasadena, California 91107

Telephone: 213 449-0016

June 24, 1976

Mr. Ken Bills
Aerojet Solid Propulsion Co.
Post Office Box 13400
Sacramento, California 95813

Dear Mr. Bills:

Thank you for giving me an opportunity to comment on transducer stability: how to approach getting it, our experience with it, and to bring you up to date on some new developments in our laboratory. My comments will be brief; I shall be happy to amplify any portion of them at an appropriate forum.

To achieve stability (to whatever degree) the following should be done: (the order of presentation does not indicate importance; we discuss herein bonded strain gage devices although comparable criteria can be set forth for other devices we make, such as capacitance transducers)

1. Specify the degree of stability desired at the beginning of the program. Designing for stability, whether in instrument design or test program protocol must start with a hard number, whether as a design goal or a minimum requirement.

This figure must specify load conditions, environmental conditions, duration of desired stability; differentiation between allowable short term and long term drift rates; differentiation between conformance to a known, unidirectional drift rate and random excursions from an unpredictable baseline.

Such detail is not necessary if one can accept a large transducer (say a thin film type), with only moderate overload conditions, which is produced in large commercial quantities, and which can be replaced by the manufacturer if it falls out of specification. But if one wants to resolve 1 psi in a 450 psi transducer the size of a shirt button, with a redundant backup sensor, in an inaccessible location, and such devices must be manufactured to order in limited quantities, very great care must be taken to define what is desired.

2. Regardless of how transducer stability is defined, the tests to be performed which define acceptable instruments should be set forth. I differentiate between "desired stability" and "tests performed" so that the nature of the

compromises which must be made between economically feasible testing and sufficiently predictive testing are set forth, and the implicit limitations be realized. Is 0.1% F.S. stability per month under no load, room temperature conditions, unpotted, in the second month after manufacture predictive of 1% F.S. per month stability after one year in the field, in situ, under load conditions, after prior proof pressure testing? How does one know, at reasonable cost, the relationship between test and field conditions, for a new design?

3. Regardless of how stability or test conditions are defined, we believe that for miniaturized, hand assembled, limited quantity production devices, test conditions should include

a. Separate test beams, instrumented by the same techniques, to separate the variables of transducer design from proper sensor installation techniques.

b. 100% stability testing, all transducers, all lots. We test for at least one month -- ! -- on our commercial implantable products, (which are installed in "inaccessible" locations), we have found it pays, and we will be expanding the scope of our testing program. Of necessity, this involves additional delay in delivery of from 2 - 3 months.

4. Field measurements of transducer characteristics (not output, but bridge impedance, comp resistor values, megohm leakage to ground, forward and reverse resistance) and of signal conditioner characteristics (using very high stability dummy bridges) must be routinely incorporated in test procedures, and transducer anomalies reported regularly to the manufacturer. Recovered failed units should have thoroughgoing failure analysis by both user and manufacturer.

5. A long term transducer development and supply program should be instituted. Long term does not mean sequential short term, rapid procurement contracts. I suggest 2 to 5 years with one or two sources is realistic. The small size and comparatively low cost (as compared to test program costs) of individual transducers does not mean that the instruments are not complex. Further, if experience in design and manufacture of instruments is diffuse or intermittent, programs may, perforce, always have to start anew.

6. All desired parameters of transducers besides stability should be specified in mechanical or electrical terms. It is not enough to state that a transducer is not interactive with some propellant, nor that it be intrinsically safe. The stiffness of a diaphragm, whether in μin/psi deflection at the center, or volumetric compliance (in^3/psi), or ratio of deflection to radius, or whatever, the relationship between each gage strain and diaphragm distortion, etc., should be stated unambiguously. Ditto voltages, current, heat rise, etc.

For whatever it is worth, I have yet to see a transducer specification which has adequately addressed itself to all the parameters significant to propellant stress testing. One of the nice cop-outs is to specify an "error-band," so one can be a purist and say that was (was not) considered in the specification. I do not mean to be contentious, but avoidance of detail in specification does avoid tediousness in reading or writing of the specification, does specify a simplistic and (perhaps) attractive error band, but promulgates downstream exceptions to the specification or arguments as to just what the error band meant.

Now a word about our more recent experience:

a. As noted above, we 100% stability test all our pressure transducers, whether or not customer required, as an internal control device.

b. We now EB weld all transducers required to be stable. EB welding does not improve stability; it does seem to assure that initially observed stability is continued.

c. Our standard (epoxied gages) implantable line (Titanium) seems to slip between 1 - 2 $\mu\varepsilon$/month (top 25%), 2 - 4 $\mu\varepsilon$/month (top 50%). I would expect better results from epoxy gaged steel or Kovar, but we have no current data.

d. We believe anodic bonding (strain gages to glass to Kovar) offers great promise for stability: approximately 0.5 $\mu\varepsilon$ per year seems a realistic goal. We are now test bonding gages in our clean room lab.

e. We have developed miniature Titanium diaphragm/Kovar beam structures with great sensitivity. In a 2 mm. x 8 mm. dia. housing (.08 x .31 inch dia.) we have achieved outputs of 50 mV/psi with good overrange protection. Our 6 psi design is better than 0.25% accurate, our 1 psi design is 0.5% accurate, using epoxied strain gages. Stability tests on the beamed designs have not been run.

f. We are building miniature (.10 x .28 inch dia.) capacitance transducers, some with internal hybrid electronic circuitry. Results will be duly reported.

I should note that our anodic bonding development is less concerned with the basic process itself than with its adaptation to very small devices, which has required development of smaller strain gages, miniature beams, special assembly fixtures and the like.

As you know, our recent R & D work has been more intensive in multi axis micro-miniature accelerometers, to sense both linear and angular motion. This has

KONIGSBERG INSTRUMENTS, INC.

required us to move to computer design approaches, the results of which should shortly be applicable to our pressure transducer developments. Please let me know if our recent experience can be helpful to you in your own development work.

Yours very truly,

Eph Konigsberg
President

EK/mar

KONIGSBERG INSTRUMENTS, INC. Specializing in Implantable Instrumentation

APPENDIX P

CALCULATED INTERFACE STRESSES FOR THE FLEXIBLE CASE MOTOR UNDER 50 PSIG INTERNAL PRESSURIZATION AND ONE-G LATERAL ACCELERATION

CALCULATED INTERFACE STRESSES FOR THE FLEXIBLE CASE MOTOR UNDER 50 PSIG INTERNAL PRESSURIZATION AND ONE-G LATERAL ACCELERATION

Stress analyses were made of the Minuteman third stage motor when subjected to an internal pressure of 50 psi for up to 10 minutes at temperatures of 30°F, 77°F and 110°F. In addition to stress analysis of this motor subjected to 1 g lateral acceleration (resting in a horizontal position) at 110°F was made.

The pressurization analyses were performed using the TEXGAP finite element elastic computer program for the grid shown in Figure P-1 and the SA011 1-dimensional viscoelastic computer program on a cross section of the motor at mid length. The 1 g lateral acceleration analysis was performed using the TEXGAP finite element elastic computer program using the same grid as for the pressurization.

The results are to be compared with the gage readings and consequently only the results at the gages are given. Figure P-2 shows the correlation between the gage location code numbers and the gage numbers. Figure P-3 shows the interface radial stress at gage location code No. 4 versus time for internal pressure of 50 psi held for 10 minutes using average aged propellant properties (T = 30°F).

Table P-1 shows the interface normal and shear stresses at all the gage location code numbers for 50 psi internal pressure held for 10 minutes at 30°F, 77°F and 110°F. Table P-2 shows the interface normal and shear stresses at all the gage location code numbers for 1 g lateral acceleration at 110°F (0° azimuth is at the bottom).

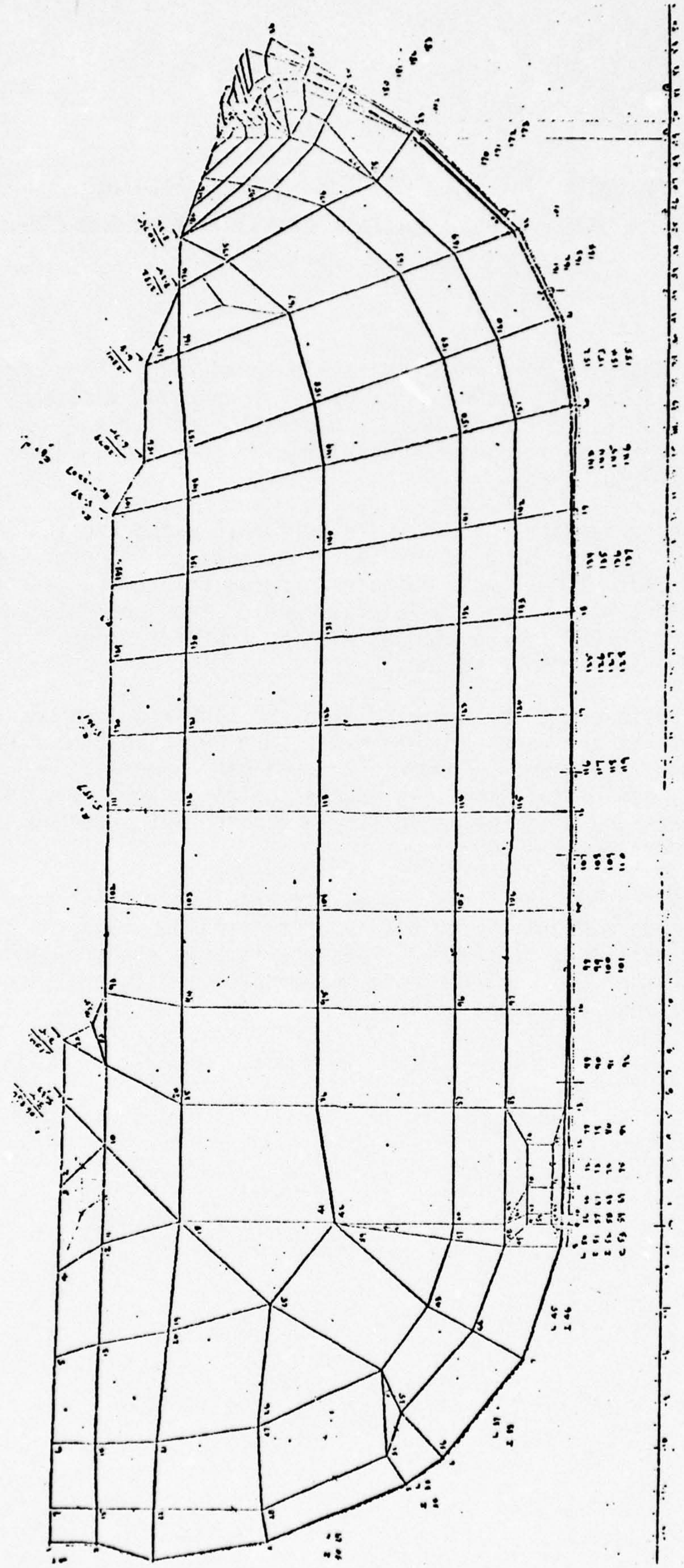


FIGURE P-1. FINITE ELEMENT GRIDWORK USED IN THE ANALYSIS OF THE MINUTEUMAN III THIRD STAGE MOTOR

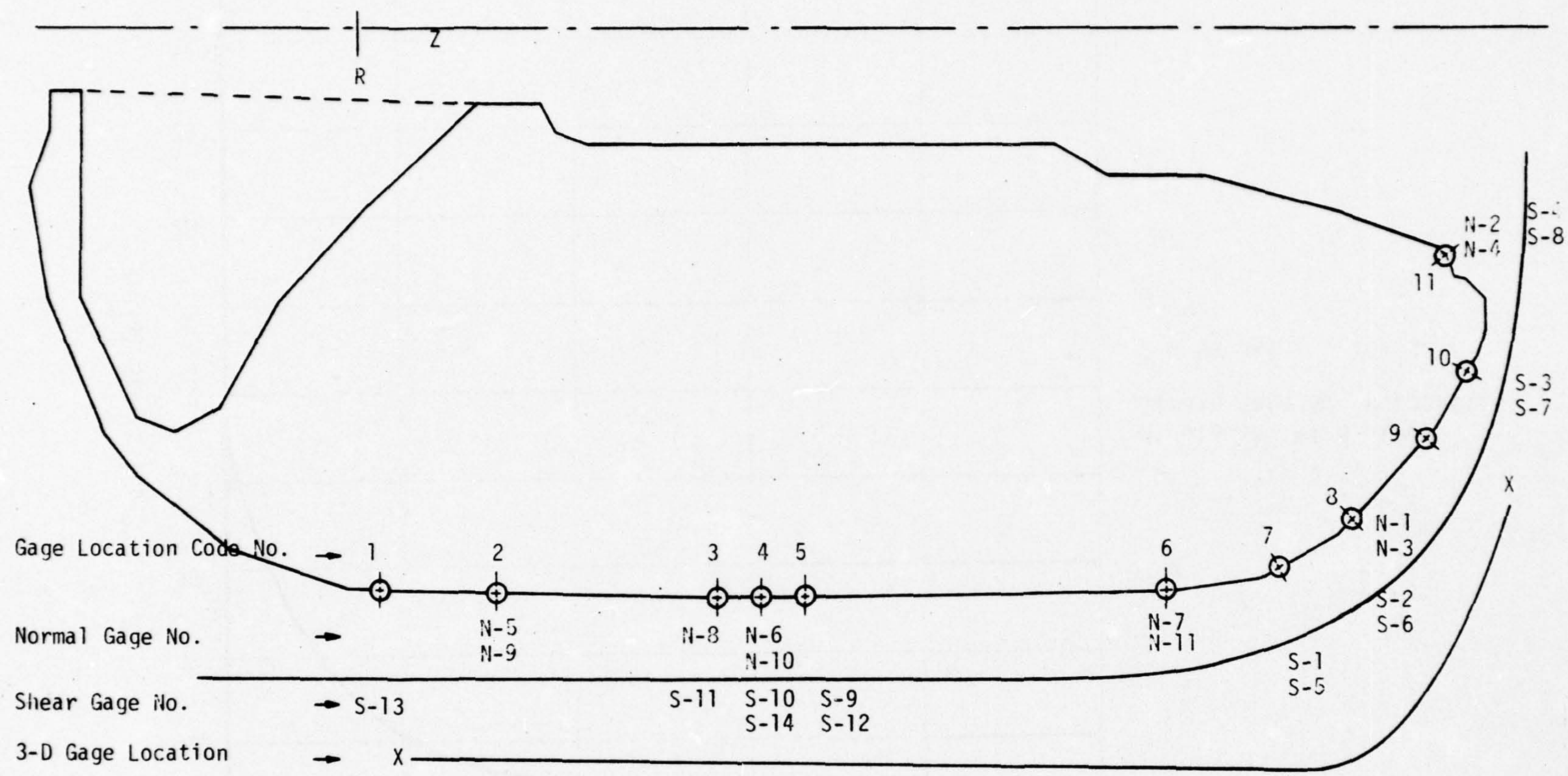


FIGURE P-2. CORRELATION BETWEEN GAGE LOCATION CODE NUMBERS AND GAGE NUMBERS

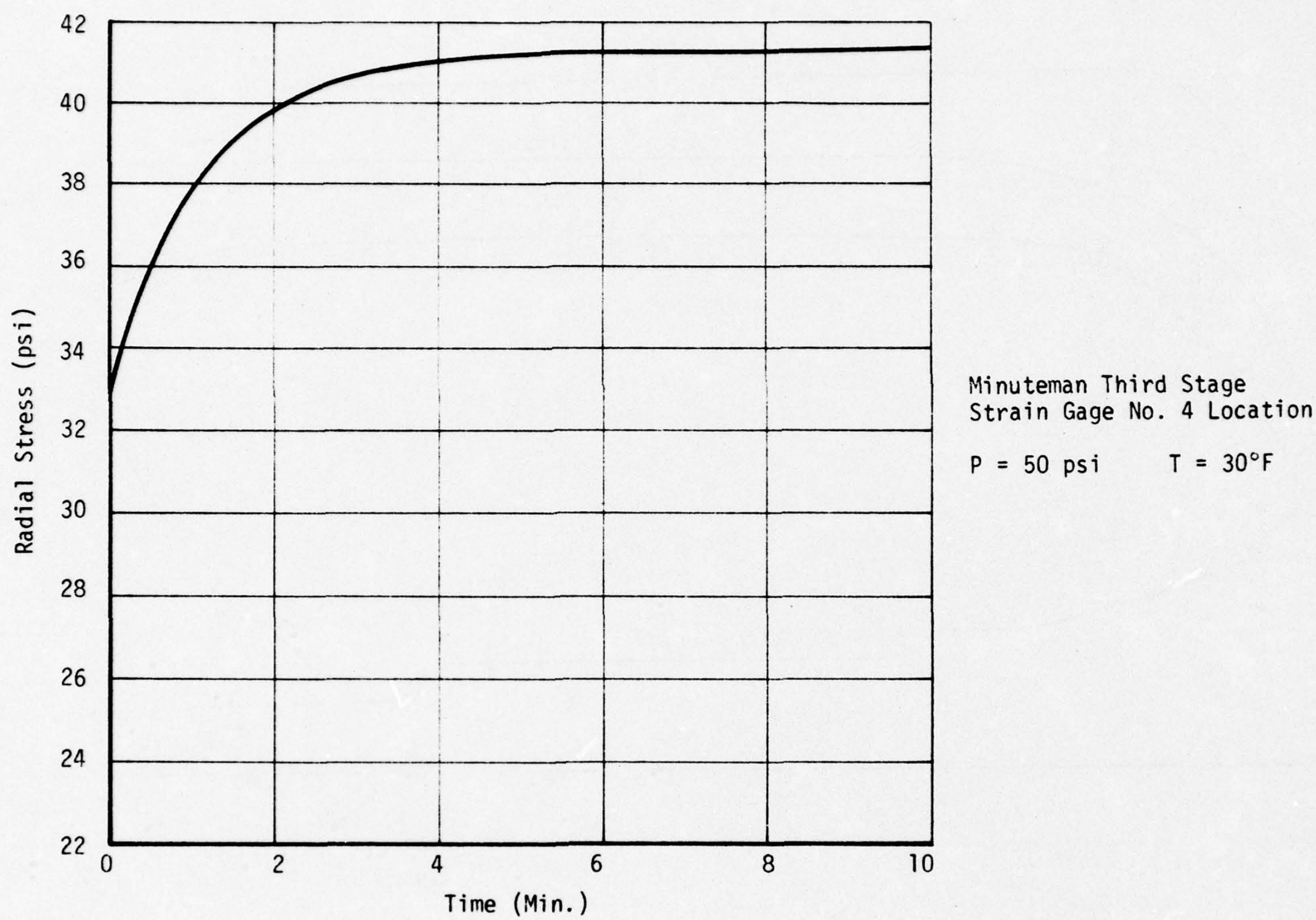


FIGURE P-3. INTERFACE RADIAL STRESS VS TIME FOR AVERAGE AGED PROPELLANT PROPERTIES

TABLE P-1

INTERFACE NORMAL AND SHEAR STRESSES AT ALL THE GAGE LOCATION CODE NUMBERS FOR 50 P.S.I. INTERNAL PRESSURE HELD FOR 10 MINUTES AT 30°F, 77°F AND 110°F

Gage Location Code No.	σ_N(psi) +1σ Modulus	τ_{rz}(psi) +1σ Modulus	σ_N(psi) Mean Modulus	τ_{rz}(psi) Mean Modulus	σ_N(psi) -1σ Modulus	τ_{rz}(psi) -1σ Modulus	
	(Ep = 619 psi)		(Ep = 530 psi)		(Ep = 441 psi)		Temperature = 30°F
1	-47.90	5.012	-48.3	4.32	-48.53	3.60	
2	-46.31	2.66	-46.8	2.30	-47.3	1.91	
3	-45.84	1.64	-46.4	1.72	-47.0	1.19	
4	-45.66	1.47	-46.2	1.28	-46.9	1.07	
5	-45.47	1.31	-46.1	1.14	-46.7	.95	
6	-43.95	.71	-44.2	.51	-45.2	.43	
7	-44.55	.30	-47.0	.27	-47.5	.23	
8	-45.16	-.12	-45.6	-.08	-46.3	-.06	
9	-44.9	-.12	-44.9	-.08	-45.7	-.06	
10	-45.2	+.3	-45.2	+.27	-46.0	+.23	
11	-34.5	3.7	-36.0	3.11	-38.4	2.59	
	(Ep = 369 psi)		(Ep = 316 psi)		(Ep = 263 psi)		Temperature = 77°F
1	-48.8	3.01	-49.0	2.57	-49.2	2.14	
2	-47.8	1.60	-48.1	1.37	-48.4	1.14	
3	-47.5	1.20	-47.9	1.03	-48.2	0.85	
4	-47.4	0.89	-47.7	0.76	-48.1	0.64	
5	-47.3	0.79	-47.7	0.68	-48.1	0.56	
6	-46.0	0.36	-46.5	0.30	-47.1	0.25	
7	-47.9	0.19	-48.2	0.16	-48.5	0.13	
8	-46.9	-0.06	-47.4	-0.05	-47.8	-0.04	
9	-46.4	-0.06	-46.9	-0.05	-47.5	-0.04	
10	-46.7	0.19	-47.1	0.16	-47.6	0.13	
11	-40.3	2.17	-41.6	1.85	-43.1	1.54	
	(Ep = 306 psi)		(Ep = 262 psi)		(Ep = 218 psi)		Temperature = 110°F
1	-49.0	2.49	-49.2	2.14	-49.3	1.78	
2	-48.2	1.33	-48.4	1.14	-49.5	0.95	
3	-47.9	0.99	-48.2	0.85	-48.5	0.71	
4	-47.8	0.74	-48.1	0.63	-48.4	0.53	
5	-47.7	0.66	-48.1	0.56	-48.4	0.47	
6	-46.6	0.29	-47.1	0.25	-47.6	0.21	
7	-48.3	0.16	-48.5	0.13	-48.8	0.11	
8	-47.5	-0.05	-47.8	-0.04	-48.2	-0.03	
9	-47.1	-0.05	-47.5	-0.04	-47.9	-0.03	
10	-47.2	0.16	-47.6	0.13	-48.0	0.11	
11	-41.9	1.80	-43.1	1.54	-44.2	1.28	

TABLE P-2

INTERFACE NORMAL AND SHEAR STRESSES FOR 1g

LATERAL ACCELERATION LOADING CONDITION T = 110°F

Gage Location Code No.	0° Azimuth			180° Azimuth			90° and 270° Azimuths			
	σ_N (psi)	τ_{rz} (psi)	$\tau_{r\theta}$ (psi)	σ_N (psi)	τ_{rz} (psi)	$\tau_{r\theta}$ (psi)	σ_N (psi)	τ_{rz} (psi)	$\tau_{r\theta}$ at 90° (psi)	τ_r at 270° (psi)
1	-3.686	-0.72	0	3.686	0.72	0	0	0	0.657	-0.657
2	-1.98	-0.111	0	1.98	0.111	0	0	0	0.196	-0.196
3	-1.663	+0.033	0	1.663	-0.033	0	0	0	0.069	-0.069
4	-1.628	0.038	0	1.628	-0.038	0	0	0	0.063	-0.063
5	-1.594	0.044	0	1.594	-0.044	0	0	0	0.057	-0.057
6	-1.50	0.035	0	1.50	-0.035	0	0	0	0.061	-0.061
7	-1.3	0.020			-0.020					
8	-1.08	0.030			-0.030					
9	-1.0	0.044			-0.044					
10	-0.80	+0.050			-0.050					
11	-0.562	-0.255			+0.255					

APPENDIX Q

NONLINEAR GAP PROGRAM

(TEXGAP-2D NONLINEAR)

MATRIX DERIVATIONS

AND

INPUT INSTRUCTIONS

NONLINEAR GAP PROGRAM (TEXGAP-2D NONLINEAR) MATRIX DERIVATIONS AND INPUT INSTRUCTIONS

A. INTRODUCTION

This appendix presents supporting information for Volume I, Section 14B, Geometrically Nonlinear Analysis of Axisymmetric Shells. Included are the derivations of the pertinent matrices for the geometric nonlinear analysis modifications and the input instructions which describe the nonlinear option cards required to execute the new program.

For the convenience of the reader the input instructions are given first, then the more detailed matrix derivations are presented.

B. INPUT INSTRUCTIONS

Reference Q-1 describes the input required for the basic TEXGAP program; only the command card format with the following changes are required to execute the nonlinear analysis.

<u>COMMAND MODE CARD</u> (Page 11 of Reference Q-1)

AXISYM, nldinc, [jprint], [a_r, a_θ, a_z, ω]

nldinc <0> = Number of load increments (20 max)

nldinc ≤ 0 = Only the linear analysis is performed.

if nldinc >0 = Two additional cards are required.

1) Control Parameters card
2) Load Scale Factors card

[jprint <4>] is the level of printed output required

jprint ≥ 2 stresses are output

jprint ≥ 3 strains are output

jprint ≥ 4 displacements are output

[a_r, a_θ, a_z, ω, <0>] are the body force accelerations associated with radial, hoop, axial, and spin effects.

CONTROL PARAMETERS CARD (Skip if nldinc ≤ 0)

nsinc <1>, nnewt <0> , nmnewt <0> , itmax <20>, tol <0.001>, iout <0>

nsinc = Number of successive load increments during the loading path, at the end of which interations are required to satisfy equilibrium.

nnewt = Number of successive Newton iterations following an incremental loading or a Modified Newton iteration.

nmnewt = Number of successive Modified Newton iterations following a Newton iteration.

itmax = Maximum number of iterations allowed at each specified load level.

Note: itmax $\geq$ nnewt + nmnewt + nnewt + nmnewt + ...

tol = Error tolerance. Iterations stop when either the number of iterations exceed itmax or when:

$$\max \left| \frac{u_i^n - u_i^{n-1}}{u_i^n} \right| \leq \text{tol}$$

where: u_i^n is the displacement of i^{th} node at n^{th} iteration.

iout = Output option

if iout = 0: No intermediate prints are required.
1: Print displacements after each incremental loading and after each convergence.
2: Print displacements after each incremental loading and after each iteration.

LOAD SCALE FACTORS CARD (Skip if nldinc $\leq$ 0)

$f_1, f_2, f_3, \ldots, f_{nldinc}$

Note: The load on the structure at i^{th} load increment will be f_i x applied load.

B. MATRIX DERIVATIONS

Axisymmetric Problems

Geometrically Nonlinear Analysis

Strain Displacement Relations

$$e_{ij} = \frac{1}{2}\left(u_i|_j + u_j|_i\right) + \frac{1}{2}u^k|_i u_k|_j$$

$$= e_{ij}^{L} + e_{ij}^{NL} \qquad \text{(Tensor Components)}$$

where

$$e_{ij}^{L} = \frac{1}{2}\left(u_i|_j + u_j|_i\right)$$

$$e_{ij}^{NL} = \frac{1}{2}u^k|_i u_k|_j$$

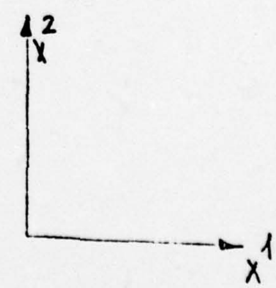
For Axisymmetric Solids

$$e_{\alpha\beta} = \frac{1}{2}\left(u_{\alpha,\beta} + u_{\beta,\alpha} + u^{\mu}{}_{,\alpha}u_{\mu,\beta}\right) \qquad \alpha,\beta,\mu = 1,2$$

$$e_{\alpha 3} = 0$$

$$e_{33} = \frac{r^2}{2}\left(2\frac{u_1}{r} + \frac{u_1^2}{r^2}\right)$$

$$= r^2\left(\frac{u_1}{r} + \frac{u_1^2}{2r^2}\right)$$



Physical Components of Strain

$$\epsilon_{ij} = \sqrt{g^{ii}}\sqrt{g^{jj}}\; e_{ij} \qquad u_i = u_i \sqrt{g^{ii}}$$

$$x^1 = r \quad x^2 = Z \quad x^3 = \theta \qquad g^{11} = 1 \quad g^{22} = \frac{1}{r^2} \quad g^{33} = 1$$

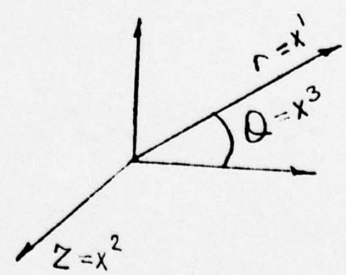
$$u_r = u_1 \quad u_Z = u_2 \quad u_\theta = u_3/r$$

$$\epsilon_{rr} = \epsilon_{rr}^{L} + \epsilon_{rr}^{NL} = \frac{\partial u_r}{\partial r} + \frac{1}{2}\left[\left(\frac{\partial u_r}{\partial r}\right)^2 + \left(\frac{\partial u_z}{\partial r}\right)^2\right]$$

$$\epsilon_{ZZ} = \epsilon_{ZZ}^{L} + \epsilon_{ZZ}^{NL} = \frac{\partial u_z}{\partial Z} + \frac{1}{2}\left[\left(\frac{\partial u_r}{\partial Z}\right)^2 + \left(\frac{\partial u_z}{\partial Z}\right)^2\right]$$

$$\epsilon_{rZ} = \frac{1}{2}\left(\frac{\partial u_r}{\partial Z} + \frac{\partial u_z}{\partial r}\right) + \frac{1}{2}\left(\frac{\partial u_r}{\partial r}\frac{\partial u_r}{\partial Z} + \frac{\partial u_z}{\partial r}\frac{\partial u_z}{\partial Z}\right)$$

$$\epsilon_{\theta\theta} = \frac{u_r}{r} + \frac{u_r^2}{2r^2}$$



$$\underset{\sim}{\epsilon}_L^T = [\epsilon_{rr}^L, \epsilon_{zz}^L, \epsilon_{\theta\theta}^L, 2\epsilon_{rz}^L]$$

$$\underset{\sim}{\epsilon}_{NL}^T = [\epsilon_{rr}^{NL}, \epsilon_{zz}^{NL}, \epsilon_{\theta\theta}^{NL}, 2\epsilon_{rz}^{NL}]$$

Strain Energy

$$U = \frac{1}{2}\int_V \sigma_{ij}\,\epsilon_{ij}\,dV = \frac{1}{2}\int_V E_{ijkl}\,\epsilon_{kl}\,\epsilon_{ij}\,dV$$

$$= \frac{1}{2}\int_V \underset{\sim}{\sigma}^T \underset{\sim}{\epsilon}\,dV$$

$$\underset{\sim}{\sigma}^T = [\sigma_{rr}^L, \sigma_{zz}^L, \sigma_{\theta\theta}^L, \sigma_{rz}^L] + [\sigma_{rr}^{NL}, \sigma_{zz}^{NL}, \sigma_{\theta\theta}^{NL}, \sigma_{rz}^{NL}]$$

$$= \underset{\approx}{D}\,\underset{\sim}{\epsilon}$$

Therefore,

$$U = \frac{1}{2}\int_V \left(\underset{\sim}{\epsilon}_L^T \underset{\approx}{D}\,\underset{\sim}{\epsilon}_L + 2\,\underset{\sim}{\epsilon}_L^T \underset{\approx}{D}\,\underset{\sim}{\epsilon}_{NL} + \underset{\sim}{\epsilon}_{NL}^T \underset{\approx}{D}\,\underset{\sim}{\epsilon}_{NL}\right) dV$$

Nodal point displacement vector

$$\underset{\sim}{\delta} = \begin{bmatrix} \underset{\sim}{u} \\ \\ \underset{\sim}{v} \end{bmatrix}_{2n\times 1}$$

Where
$$\underset{\sim}{u}^T = [u_r^1, u_r^2, u_r^3, \ldots\ldots, u_r^n]$$
$$\underset{\sim}{v}^T = [u_z^1, u_z^2, \ldots\ldots, u_z^n]$$

n = total # of nodes in an element

$$U = \underset{\sim}{\delta}^T \left[\frac{1}{2}\underset{\approx}{K} + \frac{1}{6}\underset{\approx}{K1} + \frac{1}{12}\underset{\approx}{K2} \right] \underset{\sim}{\delta}$$

Introducing the shape functions N^{α} such that

$$u_i = N^{\alpha} u_i^{\alpha} \qquad \alpha = 1, 2, \ldots, n$$
$$i = 1, 2$$

or $u_r = \underset{\sim}{N}^T \underset{\sim}{u}$

$$u_z = \underset{\sim}{N}^T \underset{\sim}{v}$$

$$\underset{\sim}{\epsilon}_L = \begin{bmatrix} \epsilon^L_{rr} \\ \epsilon^L_{zz} \\ \epsilon^L_{\theta\theta} \\ 2\epsilon^L_{rz} \end{bmatrix} = \left[\begin{array}{c|c} \underset{\sim}{N}^T_{,r} & \underset{\sim}{0} \\ \underset{\sim}{0} & \underset{\sim}{N}^T_{,z} \\ \hline \frac{1}{r}\underset{\sim}{N}^T & \underset{\sim}{0} \\ \hline \underset{\sim}{N}^T_{,z} & \underset{\sim}{N}^T_{,r} \end{array}\right] \left[\begin{array}{c} \underset{\sim}{u} \\ \hline \underset{\sim}{v} \end{array}\right] = \underset{\approx}{B}_{4\times 2n}\ \underset{\sim}{\delta}_{2n\times 1}$$

or

$$\underset{\approx}{B} = \left[\begin{array}{c|c} \underset{\sim}{N}^T_{,r} & \underset{\sim}{0} \\ \hline \underset{\sim}{0} & \underset{\sim}{N}^T_{,z} \\ \hline \frac{1}{r}\underset{\sim}{N}^T & \underset{\sim}{0} \\ \underset{\sim}{N}^T_{,z} & \underset{\sim}{N}^T_{,r} \end{array}\right]_{4\times 2n}$$

$$\underset{\sim}{\epsilon}_{NL} = \begin{bmatrix} \epsilon^{NL}_{rr} \\ \epsilon^{NL}_{zz} \\ \epsilon^{NL}_{\theta\theta} \\ 2\epsilon^{NL}_{rz} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \underset{\sim}{u}^T \underset{\sim}{N}_{,r}\underset{\sim}{N}^T_{,r}\underset{\sim}{u} + \underset{\sim}{v}^T\underset{\sim}{N}_{,r}\underset{\sim}{N}^T_{,r}\underset{\sim}{v} \\ \underset{\sim}{u}^T \underset{\sim}{N}_{,z}\underset{\sim}{N}^T_{,z}\underset{\sim}{u} + \underset{\sim}{v}^T\underset{\sim}{N}_{,z}\underset{\sim}{N}^T_{,z}\underset{\sim}{v} \\ \frac{1}{r^2}\underset{\sim}{u}^T\underset{\sim}{N}\,\underset{\sim}{N}^T\underset{\sim}{u} \\ \underset{\sim}{u}^T(\underset{\sim}{N}_{,r}\underset{\sim}{N}^T_{,z}+\underset{\sim}{N}_{,z}\underset{\sim}{N}^T_{,r})\underset{\sim}{u} + \underset{\sim}{v}^T(\underset{\sim}{N}_{,r}\underset{\sim}{N}_{,z}+\underset{\sim}{N}_{,z}\underset{\sim}{N}^T_{,r})\underset{\sim}{v} \end{bmatrix}_{4\times 1}$$

$$= \frac{1}{2}\underset{\approx}{H}_{4\times 2n}(\underset{\sim}{\delta})\underset{\sim}{\delta} \quad \text{or } \frac{1}{2}\delta^T H^T$$

Note: $\dfrac{\partial \underset{\sim}{\epsilon}_{NL}}{\partial \underset{\sim}{\delta}} = \underset{\approx}{H}(\underset{\sim}{\delta}) \qquad \dfrac{\partial \epsilon_{NL}}{\partial \delta^T} = \underset{\approx}{H}^T(\underset{\sim}{\delta})$

Where

$$\underset{\sim}{H}(\underset{\sim}{S}) = \begin{bmatrix} \underset{\sim}{S}^T \underset{\approx}{H}_{rr} \\ \underset{\sim}{S}^T \underset{\approx}{H}_{zz} \\ \underset{\sim}{S}^T \underset{\approx}{H}_{\theta\theta} \\ \underset{\sim}{S}^T \underset{\approx}{H}_{rz} \end{bmatrix} = \begin{bmatrix} \bar{\underset{\sim}{H}}^T_{rr_{1\times 2n}} \\ \bar{\underset{\sim}{H}}^T_{zz} \\ \bar{\underset{\sim}{H}}^T_{\theta\theta} \\ \bar{\underset{\sim}{H}}^T_{rz} \end{bmatrix}_{4\times 2n}$$

$$\underset{\approx}{H}_{rr} = \left[\begin{array}{c|c} \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,r_{n\times n}} & \underset{\approx}{0}_{n\times n} \\ \hline \underset{\approx}{0} & \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,r} \end{array}\right]_{2n\times 2n} ; \quad \bar{\underset{\sim}{H}}^T_{rr} = \left[\underset{\sim}{u}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,r} \; , \; \underset{\sim}{v}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,r} \right]_{1\times 2n}$$

$$\underset{\approx}{H}_{zz} = \left[\begin{array}{c|c} \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,z_{n\times n}} & \underset{\approx}{0}_{n\times n} \\ \hline \underset{\approx}{0} & \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,z} \end{array}\right]_{2n\times 2n} ; \quad \bar{\underset{\sim}{H}}^T_{zz} = \left[\underset{\sim}{u}^T \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,z} \; , \; \underset{\sim}{v}^T \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,z} \right]_{1\times 2n}$$

$$\underset{\approx}{H}_{rz} = \left[\begin{array}{c|c} \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,z} + \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,r_{n\times n}} & \underset{\approx}{0} \\ \hline \underset{\approx}{0}_{n\times n} & \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,z} + \underset{\sim}{N}_{,z} \underset{\sim}{N}^T_{,r} \end{array}\right]_{2n\times 2n} ; \quad \bar{\underset{\sim}{H}}^T_{rz} = \left[2\underset{\sim}{u}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,z} \;\middle|\; 2\underset{\sim}{v}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}^T_{,z} \right]_{4\times 2n}$$

$$u^T(N_{,r} N^T_{,z} + N_{,z} N^T_{,r})$$

$$\underset{\approx}{H}_{\theta\theta} = \frac{1}{r^2} \left[\begin{array}{c|c} \underset{\sim}{N} \underset{\sim}{N}^T_{n\times n} & \underset{\approx}{0} \\ \hline \underset{\approx}{0} & \underset{\approx}{0} \end{array}\right]_{2n\times 2n} ; \quad \bar{\underset{\sim}{H}}^T_{\theta\theta} = \frac{1}{r^2} \left[\underset{\sim}{u}^T \underset{\sim}{N} \underset{\sim}{N}^T \;\middle|\; \underset{\approx}{0} \right]_{1\times 2n}$$

$$\underset{\approx}{K1} = \underset{\approx}{K1}_{\sigma} + \underset{\approx}{K1}_{r}$$

Where $\underset{\approx}{K1}_{\sigma}$ is the first order initial stress matrix and $\underset{\approx}{K1}_{r}$ is the first order initial displacement (or rotation) matrix.

$$\underset{\approx}{K1}_{\sigma} = \begin{bmatrix} \overline{\overline{\underset{\approx}{K1}}}_{\sigma} & \underset{\approx}{0}_{n\times n} \\ \underset{\approx}{0}_{n\times n} & \overline{\overline{\underset{\approx}{K1}}}_{\sigma} \end{bmatrix}_{2n\times 2n}$$

where

$$\overline{\overline{\underset{\approx}{K1}}}_{\sigma} = \int_V \Big[\sigma_{rr}^{L} \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,r}^{T} + \sigma_{zz}^{L} \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,z}^{T} + \sigma_{rz}^{L} \left(\underset{\sim}{N}_{,r} \underset{\sim}{N}_{,z}^{T} + \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,r}^{T} \right) + \frac{1}{r^2} \sigma_{\theta\theta}^{L} \underset{\sim}{N} \underset{\sim}{N}^{T} \Big] dV$$

$$\overline{\underset{\approx}{K1}}_{\sigma} = \int_V \Big[\sigma_{rr}^{L} \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,r}^{T} + \sigma_{zz}^{L} \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,z}^{T} + \sigma_{rz}^{L} \left(\underset{\sim}{N}_{,r} \underset{\sim}{N}_{,z}^{T} + \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,r}^{T} \right) \Big] dV$$

or $$\overline{\overline{\underset{\approx}{K1}}}_{\sigma} = \overline{\underset{\approx}{K1}}_{\sigma} + \int_V \frac{1}{r^2} \sigma_{\theta\theta}^{L} \underset{\approx}{N} \underset{\approx}{N}^{T} dV$$

$$\underset{\approx}{K1}_{\delta} = \int_V \left[\underset{\approx}{H}^T \underset{\approx}{D} \underset{\approx}{B} + \underset{\approx}{B}^T \underset{\approx}{D} \underset{\approx}{H} \right] dV$$

Similarly

$$\underset{\approx}{K2} = \underset{\approx}{K2}_{\sigma} + \underset{\approx}{K2}_r$$

where $\underset{\approx}{K2}_{\sigma}$ is the second order initial stress matrix and $\underset{\approx}{K2}_r$ is the second order initial displacement (or rotation) matrix

and

$$\underset{\approx}{K2}_{\sigma} = \begin{vmatrix} \overline{\overline{\underset{\approx}{K2}}}_{\sigma} & \\ & \overline{\underset{\approx}{K2}}_{\sigma} \end{vmatrix}$$

$$\overline{\underset{\approx}{K2}}_{\sigma} = \frac{1}{2}\int_V \left[\sigma_{rr}^{NL} \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,r}^T + \sigma_{zz}^{NL} \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,z}^T + \sigma_{rz}^{NL} \left(\underset{\sim}{N}_{,r} \underset{\sim}{N}_{,z}^T + \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,r}^T \right) \right] d$$

$$\overline{\overline{\underset{\approx}{K2}}}_{\sigma} = \overline{\underset{\approx}{K2}}_{\sigma} + \int_V \frac{1}{r^2} \sigma_{\theta\theta}^{NL} \underset{\sim}{N} \underset{\sim}{N}^T dV$$

$$\underset{\approx}{K2}_r = \int_V \underset{\approx}{H}^T(\underset{\sim}{\delta}) \underset{\approx}{D} \underset{\approx}{H}(\underset{\sim}{\delta}) dV$$

For Orthrophic Materials

$$\underset{\sim}{D} = \begin{bmatrix} D_{11} & D_{12} & D_{13} & D_{14} \\ D_{21} & D_{22} & D_{23} & D_{24} \\ D_{31} & D_{32} & D_{33} & D_{34} \\ D_{41} & D_{42} & D_{43} & D_{44} \end{bmatrix}$$

$$\sigma_{rr}^{L} = D_{11}\,\epsilon_{rr}^{L} + D_{12}\,\epsilon_{zz}^{L} + 2D_{14}\,\epsilon_{rz}^{L} + D_{13}\,\epsilon_{\theta\theta}^{L}$$

$$\sigma_{zz}^{L} = D_{21}\,\epsilon_{rr}^{L} + D_{22}\,\epsilon_{zz}^{L} + 2D_{24}\,\epsilon_{rz}^{L} + D_{23}\,\epsilon_{\theta\theta}^{L}$$

$$\sigma_{\theta\theta}^{L} = D_{31}\,\epsilon_{rr}^{L} + D_{32}\,\epsilon_{zz}^{L} + 2D_{34}\,\epsilon_{rz}^{L} + D_{33}\,\epsilon_{\theta\theta}^{L}$$

$$\sigma_{rz}^{L} = D_{41}\,\epsilon_{rr}^{L} + D_{42}\,\epsilon_{zz}^{L} + 2D_{44}\,\epsilon_{rz}^{L} + D_{43}\,\epsilon_{\theta\theta}^{L}$$

where

$$\epsilon_{rr}^{L} = \underset{\sim}{N}_{,r}^{T}\,\underset{\sim}{u}$$

$$\epsilon_{zz}^{L} = \underset{\sim}{N}_{,z}^{T}\,\underset{\sim}{v}$$

$$2\epsilon_{rz}^{L} = \left(\underset{\sim}{N}_{,z}^{T}\,\underset{\sim}{u} + \underset{\sim}{N}_{,r}^{T}\,\underset{\sim}{v}\right)$$

$$\epsilon_{\theta\theta}^{L} = \frac{1}{r}\,\underset{\sim}{N}\,\underset{\sim}{u}$$

Similarly $\underset{\sim}{\sigma}_{NL} = \underset{\approx}{D}\, \underset{\sim}{\epsilon}_{NL}$

where

$$\epsilon_{rr}^{NL} = \frac{1}{2}\left(\underset{\sim}{u}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,r}^T \underset{\sim}{u} + \underset{\sim}{v}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,r}^T \underset{\sim}{v}\right)$$

$$\epsilon_{zz}^{NL} = \frac{1}{2}\left(\underset{\sim}{u}^T \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,z} \underset{\sim}{u} + \underset{\sim}{v}^T \underset{\sim}{N}_{,z} \underset{\sim}{N}_{,z} \underset{\sim}{v}\right)$$

$$\epsilon_{rz}^{NL} = \frac{1}{2}\left(\underset{\sim}{u}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,z}^T \underset{\sim}{u} + \underset{\sim}{v}^T \underset{\sim}{N}_{,r} \underset{\sim}{N}_{,z}^T \underset{\sim}{v}\right)$$

$$\epsilon_{\theta\theta}^{NL} = \frac{1}{2r^2} \underset{\sim}{u}^T \underset{\sim}{N}\, \underset{\sim}{N}^T \underset{\sim}{u}$$

$$\sigma_{rr}^{NL} = D_{11}\, \epsilon_{rr}^{NL} + D_{12}\, \epsilon_{zz}^{NL} + 2 D_{14}\, \epsilon_{rz}^{NL} + D_{13}\, \epsilon_{\theta\theta}^{NL}$$

$$\sigma_{zz}^{NL} = D_{21}\, \epsilon_{rr}^{NL} + D_{22}\, \epsilon_{zz}^{NL} + 2 D_{24}\, \epsilon_{rz}^{NL} + D_{23}\, \epsilon_{\theta\theta}^{NL}$$

$$\epsilon_{\theta\theta}^{NL} = D_{31}\, \epsilon_{rr}^{NL} + D_{32}\, \epsilon_{zz}^{NL} + 2 D_{34}\, \epsilon_{rz}^{NL} + D_{33}\, \epsilon_{\theta\theta}^{NL}$$

$$\epsilon_{rz}^{NL} = D_{41}\, \epsilon_{rr}^{NL} + D_{42}\, \epsilon_{zz}^{NL} + 2 D_{44}\, \epsilon_{rz}^{NL} + D_{43}\, \epsilon_{\theta\theta}^{NL}$$

Strain Energy:

$$U = \underset{\sim}{\delta}^T \left[\frac{1}{2} \underset{\approx}{K} + \frac{1}{6} \underset{\approx}{K1}(\underset{\sim}{\delta}) + \frac{1}{12} \underset{\approx}{K2}(\underset{\sim}{\delta}^2) \right] \underset{\sim}{\delta}$$

Equilibrium Equation:

$$\left[\underset{\approx}{K} + \frac{1}{2} \underset{\approx}{K1}(\underset{\sim}{\delta}) + \frac{1}{3} \underset{\approx}{K2}(\underset{\sim}{\delta}^2) \right] \underset{\sim}{\delta} = \underset{\sim}{f}$$

Incremental Loading Method:

$$\left[\underset{\approx}{K} + \underset{\approx}{K1}(\underset{\sim}{\delta}_n) + \underset{\approx}{K2}(\underset{\sim}{\delta}_n^2) \right] \Delta \underset{\sim}{\delta}_{n+1} = \Delta \underset{\sim}{f}_{n+1}$$

where for (n + 1) st loading

$$\Delta \underset{\sim}{\delta}_{n+1} = \underset{\sim}{\delta}_{n+1} - \underset{\sim}{\delta}_n \qquad n = 0, 1, \ldots, N_{max}$$

$$\Delta \underset{\sim}{f}_{n+1} = \underset{\sim}{f}_{n+1} - \underset{\sim}{f}_n$$

Newton's Method (Iterative):

$$\left[\underset{\approx}{K} + \underset{\approx}{K1}(\underset{\sim}{\delta}_i) + \underset{\approx}{K2}(\underset{\sim}{\delta}_i^2) \right] \Delta \underset{\sim}{\delta}_{i+1} = \underset{\sim}{f} - \left[\underset{\approx}{K} + \frac{1}{2} \underset{\approx}{K1}(\underset{\sim}{\delta}_i) + \frac{1}{3} \underset{\approx}{K2}(\underset{\sim}{\delta}_i^2) \right] \underset{\sim}{\delta}$$

Where i = iteration number and iterations said to close when $\Delta \underset{\sim}{\delta}_{i+1} \approx \underset{\sim}{0}$

To calculate $\underset{\approx}{B}^T \underset{\approx}{D} \underset{\approx}{H}$

$$\underset{\approx}{B}^T_{2n\times 4}$$

Multiply $\underset{\approx}{B}^T \underset{\approx}{D}_{2n\times 4}$

$$\overline{\underset{\approx}{B}} = \underset{\approx}{B}^T \underset{\approx}{D} = \begin{bmatrix} \underset{\sim}{N}_{,r} & \underset{\sim}{0} & \frac{1}{r}\underset{\sim}{N} & \underset{\sim}{N}_{,z} \\ \underset{\sim}{0} & \underset{\sim}{N}_{,z} & \underset{\sim}{0} & \underset{\sim}{N}_{,r} \end{bmatrix}_{2n\times 4} \begin{bmatrix} D_{11} & D_{12} & D_{13} & D_{14} \\ D_{21} & D_{22} & D_{23} & D_{24} \\ D_{31} & D_{32} & D_{33} & D_{34} \\ D_{41} & D_{42} & D_{43} & D_{44} \end{bmatrix}_{4\times 4}$$

$$\overline{\underset{\approx}{B}} = \begin{bmatrix} \overline{\overline{\underset{\sim}{B}}}_{11\,n\times 1} & \overline{\overline{\underset{\sim}{B}}}_{12} & \overline{\overline{\underset{\sim}{B}}}_{13} & \overline{\overline{\underset{\sim}{B}}}_{14\,n\times 1} \\ \overline{\overline{\underset{\sim}{B}}}_{21} & \overline{\overline{\underset{\sim}{B}}}_{22} & \overline{\overline{\underset{\sim}{B}}}_{23} & \overline{\overline{\underset{\sim}{B}}}_{24\,n\times 1} \end{bmatrix}_{2n\times 4}$$

$$\underset{\sim}{\bar{\bar{B}}}_{11_{n \times 1}} = D_{11}\underset{\sim}{N}_{,r} + D_{41}\underset{\sim}{N}_{,z} + \frac{D_{31}}{r}\underset{\sim}{N}$$

$$\underset{\sim}{\bar{\bar{B}}}_{12} = D_{12}\underset{\sim}{N}_{,r} + D_{42}\underset{\sim}{N}_{,z} + \frac{D_{32}}{r}\underset{\sim}{N}$$

$$\underset{\sim}{\bar{\bar{B}}}_{13} = D_{13}\underset{\sim}{N}_{,r} + D_{43}\underset{\sim}{N}_{,z} + \frac{D_{33}}{r}\underset{\sim}{N}$$

$$\underset{\sim}{\bar{\bar{B}}}_{14} = D_{14}\underset{\sim}{N}_{,r} + D_{44}\underset{\sim}{N}_{,z} + \frac{D_{34}}{r}\underset{\sim}{N}$$

$$\underset{\sim}{\bar{\bar{B}}}_{21} = D_{21}\underset{\sim}{N}_{,z} + D_{41}\underset{\sim}{N}_{,r}$$

$$\underset{\sim}{\bar{\bar{B}}}_{22} = D_{22}\underset{\sim}{N}_{,z} + D_{42}\underset{\sim}{N}_{,r}$$

$$\underset{\sim}{\bar{\bar{B}}}_{23} = D_{23}\underset{\sim}{N}_{,z} + D_{43}\underset{\sim}{N}_{,r}$$

$$\underset{\sim}{\bar{\bar{B}}}_{24_{r \times 1}} = D_{24}\underset{\sim}{N}_{,z} + D_{44}\underset{\sim}{N}_{,r}$$

Then multiply $\underset{\approx}{\bar{B}}\ \underset{\approx}{H}$

REFERENCES FOR APPENDIX Q

Q-1. Dunham, R. S. and Becker, E. B., "TEXGAP - The Texas Grain Analysis Program", The University of Texas, TICOM Report No. 73-1 (August 1973).